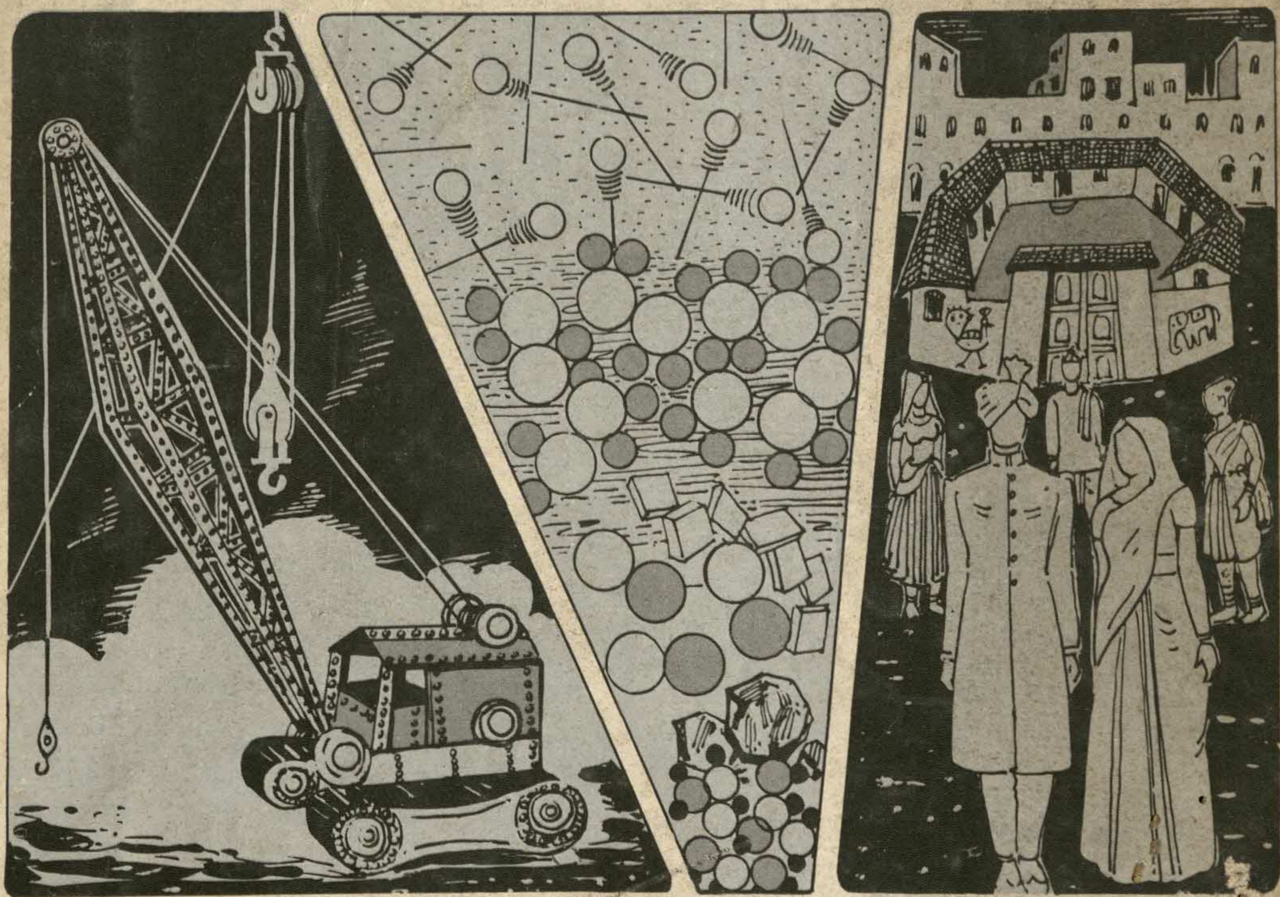
GENERAL SCIENCE

FOR PRIMARY SCHOOLS 2

A TEACHER'S HANDBOOK OF ACTIVITIES



NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

GENERAL SCIENCE
for
Primary Schools

A Teacher's Handbook of Activities

VOLUME TWO

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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FOREWORD

Education in a developing society like ours faces a challenging task, particularly if it is not restricted to a social class. On the one hand, it has to transmit the tradition and heritage of the land and its people in a manner which is acceptable to the masses brought into the stream of education by the process of increasing democratization; on the other, it has to function as an instrument of social change. An important factor in social change being science and technology, our schools should provide adequate instruction in science the aim of which should be to teach the method of scientific inquiry as much as the knowledge of scientific principles and facts. Hence in 1963, the National Council of Educational Research and Training developed as a first step, an all-India syllabus in general science for Classes I-VIII with the help of several groups of science teachers, teacher educators and science supervisors. For each area or unit of study a number of major and minor concepts were listed as a core for the development of scientific understanding of the environment. In order to help the teachers of the middle school level in developing such understanding in their pupils, a *General Science Handbook of Activities: Classes VI-VIII* was published in 1964. Our approach in the primary stage is however somewhat different. Here an attempt has been made to give to the teacher some knowledge of the concepts as well as the guidelines for using an investigatory or inquiry-based method of teaching science.

It is hoped that the present volume will help the teacher to develop new insights into science and scientific method and enable him to provide to the young child under his care some meaningful learning experience.

Shib K. Mitra

New Delhi
17 October, 1967

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CONTENTS

INTRODUCTION

This teacher's handbook is intended to help teachers of primary schools to use science effectively as part of the curriculum. The handbook is written for the primary school teachers of India, especially those who have not completed high or higher secondary school and have little or no background in science.

A primary school teacher teaches in the regional language in the village school, where there are one, two or perhaps three teachers. He teaches in a small room of a simple building; his students sit on the floor. He may or may not have suitable textbooks in science; his budget for purchasing science materials is almost zero. Yet it should not be assumed that the village teacher in India has no resources for the teaching of science. Rural children here are very close to their environment. They are surrounded by plants and animal life on their farms and in their hamlets. They are more aware of weather, climate, of water supply and problems of keeping cool than are children in larger cities.

At an early age they have learned about fuels as sources of heat and light, and about the nature of the night time sky. Many primary school children have had abundant experience in carrying on household tasks and village activities which involve the principles of science. Thus in many ways, the rural children of this country, like those of many other countries, have a remarkable start towards learning about science.

Although village schools have little or no special equipment for the teaching of science, they have many useful resources on which they can draw. There is science involved in everyday food, clothing and housing. Many science principles are illustrated on the farms, in the kitchens, and in the village bazars. Many everyday items, such as earthen pots, electric torches, glass jars, string and paper, rocks and soils, can be used to help teaching science.

It is the purpose of this handbook to help the teacher who is inexperienced in science teaching. The teacher can make use of children's experiences with everyday materials in teaching scientific principles as well as the nature of science.

Why teach science to children?

The effective way to approach the answer to this question is to analyze what is the nature of science and what is it that scientists do? Unfortunately there are wide misunderstandings about these things. There are many who believe that science is simply a collection of theories and principles, facts and formulas, special methods and scientific names. They believe that a scientist is one who has learnt all such things and is prepared to draw upon his memory in his scientific work. This description is far from accurate. Science is more than a collection of knowledge; it is also the intellectual

activity in which scientists are engaged. That is, science is not just a subject—it is also a pattern of methods for solving real problems, large and small, scientific and otherwise.

Science is also a set of attitudes about doing things and about thinking—a background of appreciations of the natural and man-made environment. When scientists work, it is true that they draw upon what they have learnt in the past. Yet memorization is not their most valuable asset. The best of human memories often fails. New ideas of science are developed very rapidly long after a scientist has finished his university training. Very typically the scientist is called upon not simply to recite what is known, but rather to find out what is not known. Thus the work of a scientist is far from being a matter of repeating learned knowledge. Research is much more of a creative process where the scientist finds new knowledge or applies existing principles to new situations.

Science does involve the learning of knowledge and of skills. But this is only a part of science. Another important aspect of science includes the methods scientists use to gain new knowledge, the attitudes involved in their behaviour. Science also includes the activities of scientists, and the role of science in society. Science is not merely what scientists know; it is also what scientists do.

These two aspects of the scientific enterprise are described in many terms: 'subject' and 'method', 'content' and 'activities', 'knowledge' and 'behaviour'. A well accepted pair of terms is used throughout these pages—'product' and 'process'.

What is meant by *product of science?* This is the side of science familiar to most teachers and students the world over. This is the side which is basically knowledge, including facts and figures, formulas and equations, principles and scientific laws. This is, indeed, the side of science to which most teaching effort in most countries has usually been directed.

By *process of science* is meant the things that scientists do. This includes the way they locate information in books and magazines, the way they learn through observation, the way they experiment (that is, manipulate the environment for purposes of special observation). This also means the way they develop ideas of what *might* be true, the way they test these ideas, and the way they communicate the ideas to others. This is the sort of thing often referred to as *scientific methods*. Not only scientists, but all men and women and boys and girls can become more successful, more satisfied individuals if they have competence along these lines.

Process of science also includes the patterns of thinking sometimes called *scientific attitudes*. This means curiosity, honest doubt, tolerance for the opinions of others, and suspension of judgement. This also includes willingness to admit when one is wrong, and an inclination to make decisions on the basis of evidence rather than tradition, superstition, or emotion. People—scientists and others—are better off if they act in these ways.

Process of science also means the role of the scientific enterprise in a modern nation. This includes the part to be played by science in improving agriculture, health, industry, communication and transport of a country. It means the function of science is to improve general standards of living and help establish personal and national security. Perhaps most of all, it means the thing that science and scientists do—they seek satisfying

explanations for the things they observe. Seen thus, science is a specialized kind of curiosity, a highly intellectual enterprise in which each and all can participate, each at his own level.

If this is the modern concept of what science really is, what has it to do with Indian children at the primary school level? There are two kinds of ways in which science affects these children.

For one thing, these children are affected as individuals growing up in a modern world which is very different than it was even one generation ago. These children are affected by much of the progress which science has brought. They use plastics, synthetic fibres and medicines which were almost unknown when their parents were young. These children are directly affected by new means of communication such as telegraph, radio and cinema and also by better methods of transportation. These children are affected by fertilizers and hybrid seeds for better crops, by irrigation and other improved methods of farming, by new standards of sanitation. They are affected by the need for population control, and by new kinds of tools and machinery, electricity and chemical power, which are being increasingly used in their daily lives. A child growing up in this changing world must learn about these new features of his environment.

Children are also affected by the ways in which scientists work. In a very real sense children must be their own science specialists. Children need to find out new information, they need to arrive at an understanding of what is going on about them, they need to make judgments and decisions concerning what they will do in many walks of life. These tasks of children are very close to the activities of scientists. Thus the *process of science* as well as the *product of science* are things which are extremely important to very young children.

There is yet another way in which science affects people through the impact that it has on the society in which they live. Improved means of communication and transportation are helping to bring even the most remote village into some kind of contact with the rest of the world. Increased production of goods and better demand for human services are changing not only our standard of living but also our patterns of daily activities. The over-crowding of population brings a new and imperative need for national efforts on birth control.

It is much more difficult for a modern child to understand science in its broadest sense than it was even a few years ago. While it is true that there is far more science to be learnt today than there was a generation ago, this is not what makes modern science learning such a large task. Rather the learning of science today is difficult because it is so complicated. The modern young person must not only know some principles of science, he must know how to apply them and he must know how to find new information when he needs it.

For these reasons we must start children on their task of learning about science as early as possible. There is ample evidence to show that children at pre-school age can learn some simple principles of science. What is more important, they can use the process of science effectively. For example, most of what children learn until they are three or four years old is learnt strictly through observation and experience—the basic tools of the laboratory scientist! Pre-school children can acquire important attitudes about science—attitudes such as

curiosity, tolerance of others' ideas, and respectful doubt of established authority. The sooner we start teaching science to young children the better. At the present level of the development of primary school education in this country, the best that can be done for all children is to start with Class I.

How should science be taught?

A valuable tool for methods of teaching science can be found in the analysis of science on the previous pages. If science is *process* and *product*, then it should be taught as such. If it is true that sheer memorization of facts and principles is not of supreme importance to a scientist, then science should not be presented in this way to children. If it is true that problem solving, decision making, creative curiosity, and effective inquiry are fundamental features of science, then these kinds of activities should be abundantly present in school science for children.

This does not mean that science teaching should not include knowledge. What it does mean is that knowledge is to be *understood* rather than merely memorized. It does mean that not all knowledge known to scientists can be included in the curriculum. Rather one must select those ideas in science which will be most useful to young people. Furthermore, the selection of science subject matter should be made in terms of broad understanding which ramify throughout human experiences. These broad understandings are often referred to as 'conceptual themes'. These are broad and sweeping ideas which cut across the conventional compartments of subject matter. These ideas have application not only in scientific laboratories but also in the daily lives of common people. The following list of fifteen conceptual themes is typical of this new approach to the selection of subject matter.

1 Every effect has its cause or causes.
2 Scales for time, position, size, and motion in space are relative, not absolute.
3 Natural laws are universal, demonstrable through time and space.
4 Dissimilarity and diversity are normal qualities in natural phenomena.
5 In spite of natural diversity, there are patterns of similarity among things in the universe; they are amenable to useful man-made system of classification.
6 Change is a normal condition in the dynamic continuity of nature.
7 In spite of natural change, the influence of heredity tends to maintain characteristics of living things from one generation to the next.
8 Interdependence and interaction with environment are universal relationships in nature.
9 Matter is particulate in nature.
10 Energy interchanges accompany every natural occurrence.
11 Energy can be transmitted in a variety of forms and manners.
12 Fields of influence extend beyond the place of their origin.
13 Equilibrium is a condition towards which all systems in the universe tend to evolve.
14 Living organisms are highly specialized systems of matter and energy.
15 The sum total of matter and energy in any isolated system remains constant.

These conceptual themes have been deliberately woven into this handbook. At many points throughout the pages of the guide, specific reference is made to one or

more of them. The suggested learning activities and the selected special sections for the teachers (For Better Understanding) focus attention on these conceptual themes and suggest to the teacher ways in which he can make them understandable to students.

What are the characteristics of children?

The science of educational psychology is adding much to the experience and wisdom of adults to help us understand better the nature of young children and the ways in which they learn. The interests and attitudes of young children vary with their age. Sometimes these characteristics vary with the environment—rural or urban—in which they happen to be placed. The atmosphere in the family and the school also contributes to their development.

A six or seven-year-old child usually shows signs of self-assertion and hates imposition by others. He is extremely inquisitive and wants to explore, feel, touch, and use all his senses. He has a keen sense of competition and wishes to outdo his peers. He fondles young animals and tries to make friends with them. He collects things such as clay, bricks, stones in the environment. He engages himself and his peers in make-believe construction, cooking and other activities. He likes to play with toys. He attempts to make them and destroy them soon after. His attention span is about fifteen minutes. Encouragement helps him a lot in his endeavours and investigation.

Very careful handling by parents and teachers is needed to develop and mould the character of a child of this age. He should not be burdened with tasks which he is incapable of doing. He needs careful and close supervision in the classroom. As his attention span is small, it will be helpful if two or three activities of different types are put into a single class period of 30-35 minutes.

The eight-year-old child just begins to think logically and makes an honest effort to express himself properly through the media available. He begins to distinguish facts from fiction. Usually, he has a great deal of energy which is manifested through physical exercises. He runs when he could walk. This energy should be properly channelled for useful purposes through activities of various types in which the child often takes great interest.

The nine-year-old child starts developing his own interests. He is less dependent on his teachers and elders than when he was younger. He can understand simple relationships of time and space and appreciate the past and the present. Often he does not accept a statement unless he really believes it. This is, therefore, just the stage when he should be directed to plan ways to find answers for the questions that he raises.

The ten-year-old child is capable of doing some rather critical thinking. He continues to be inquisitive and takes great pleasure in experimenting and finding out new things. At this age he develops special interests and likes to work in groups. He is more mature now and can understand more complicated relationships than when he was younger. He takes interest in reading books on adventure. He is increasingly able to appreciate the role of scientists and scientific achievements.

What is known about how children learn?

It is known from research in educational psychology that children do not learn best by simply being told. Rather, they learn better when they are personally involved

in activities related to the subject at hand. Briefly, children learn by doing; so do adults. It will always be necessary for students at any age level to learn much knowledge by reading it or by listening to it. Wherever possible, however, teachers should plan their programme in such a manner that children have a chance to *learn through activities*. Teaching science is not 'telling science'. Teachers need to provide rich variety of real learning experiences through which children can learn. Learnings acquired in this way are more meaningful and less forgettable than learnings acquired merely through listening and reading. Wherever possible, teachers should try to help students develop ideas about science on the basis of first-hand evidence.

Educational psychology has clearly shown that learning on the basis of meaningful activities leads to better understanding of scientific principles and to permanent learning of related facts. It is also obvious that this pattern of learning helps children learn not only the product but also the process of science. After all, the development of principles based on first-hand observation is thoroughly characteristic of the process of science.

The activities of this handbook are selected and described in such a way as to emphasize this kind of learning. At the same time, they are selected in such a way that they will lead to a knowledge of facts and an understanding of principles of science. In this way, the teaching of *science product* through an approach which emphasizes the *science process* makes for better overall learning of science from the broadest possible point of view.

This teacher's handbook is *not* intended as a course of study to be rigorously followed. Furthermore, this guide is *not* a set of lessons to be used by the teacher. Rather, the handbook is intended as a teacher's resource, a collection of ideas to which he may refer for improved teaching of science to his children.

It is very clear that patterns of teaching science vary throughout the nation. Certainly they differ from state to state, from district to district, and from school to school. The purpose of this teacher's handbook is to help each individual teacher develop the local pattern of science teaching to new levels of effectiveness.

What syllabus does this teacher's handbook follow?

This handbook is structured on the basis of the "General Science Syllabus—Classes I-VIII" published by the National Council of Educational Research and Training in 1963. There have been some modifications in the details of that syllabus, and correspondingly in this handbook. A few such examples are given below :

1 The unit on 'Energy and Work' has been rewritten and enlarged. This has been done because of the conviction that concepts of energy and work are too important to postpone until Class IV. Fortunately many of these concepts can be understood by children in the first three classes. Accordingly this unit has been enlarged and distributed among all of the first five classes.
2 The unit on 'Matter and Materials' has been given a treatment similar to that of the unit on 'Energy and Work' for the same reasons. This, too, has been enlarged and distributed among Classes I through V.
3 The unit on 'Scientists at Work' has

been distributed among all of the units of the syllabus. It is felt that the accounts of scientists' activities are more meaningful if they are taught in conjunction with a related conceptual theme or an appropriate unit of work.

4 The unit on 'Measurements' has similarly been redistributed among appropriate units. Most of the concepts formerly in that unit are now found in the units on 'Our Universe', 'Air, Water and Weather', 'Energy and Work', and 'Matter and Materials'.

In spite of these modifications in the 1963 General Science Syllabus, the teacher will have no difficulty in using this handbook to teach the older version of the syllabus.

Thus the thirteen units of the original "General Science Syllabus Classes I–VIII" have been reduced to eleven in number. For purposes of this publication these eleven units have been rearranged into three major sections. These sections are bound into three separate volumes, of which this is the second one. These three new volumes, the new arrangement of units and their new numbers are shown in the chart below:

VOLUME 1—THE EARTH-RELATED SCIENCES

Unit 1—*Our Universe* (formerly Unit 12)
Unit 2—*Air, Water and Weather* (formerly Unit 1)
Unit 3—*Rocks, Soils and Minerals* (formerly Unit 2)

VOLUME 2—THE PHYSICAL SCIENCES

Unit 4—*Energy and Work* (formerly Unit 6)
Unit 5—*Matter and Materials* (formerly Unit 7)
Unit 6—*Housing and Clothing* (formerly Unit 5)

VOLUME 3—THE BIOLOGICAL SCIENCES

Unit 7—*Living Things* (formerly Unit 8)
Unit 8—*Plant Life* (formerly Unit 9)
Unit 9—*Animal Life* (formerly Unit 10)
Unit 10—*Human Body, Health and Hygiene* (formerly Unit 3)
Unit 11—*Safety and First Aid* (formerly Unit 4)

Thus this three-volume edition of "Science for Primary Schools—a Teacher's Handbook" is arranged into three logical sections. However, this does not imply that children are to be led in their science learnings through this kind of subject-matter organization. This highly logical subject-matter organization appeals to the view of the scientist and meets the needs of curriculum workers and classroom teachers. However, it does not represent the interests of children nor the ways in which they learn.

How can this handbook be useful?

Each class level of each unit is introduced by an overview. This is intended to help the teacher to see what is involved in this unit at this class level, to realize why it is important in the education of children, and to learn what students already know about this unit.

Each of the eleven units of work at each class level is divided into major concepts. Each major concept is in turn broken into sub-concepts. The organization of the teacher's handbook is on the same pattern. Each sub-concept begins with a brief statement concerning the knowledge and understanding involved. This is intended as a

condensed lesson for the teacher. Next appear one or more learning activities which are useful in helping students understand the sub-concept. These learning activities are of several types such as:

Investigation
Discussion
Class Project
Field Observation
Interview
Familiar Experience

Whatever the type of activity, it is printed in a heavily starred box for easy identification. This heavy box includes the title of the activity, the materials needed, the instructions for carrying out the activity, and often an illustration.

In addition, each sub-concept contains one or more additional activities briefly suggested. These are printed in a lightly dotted box for easy identification. Unlike the heavily boxed activities, these are merely quick suggestions without detailed instructions.

A special kind of learning activity—'Scientists at Work'—appears several times in each unit. These selections are located immediately after an appropriate sub-concept, or at the end of a class level. Each 'Scientists at Work' activity is basically a story for children. It is intended that the teacher should read the story for thorough understanding; then he should relate it to the students using his own words and style of presentation. This is a much better procedure than simply to read 'Scientists at Work' to the class.

In many places the teacher needs additional background over and above what he might teach to children. This has been included, where needed, under the heading 'For Better Understanding'

Where can teachers get help for science teaching?

It is hoped that this handbook will interest teachers throughout the nation in a serious attempt to improve science teaching. If you are so interested, you will surely need additional help. Here are some of the ways in which you can seek and find such assistance:

(a) Keep your eyes open to the everyday materials familiar to children. Once you know how to look for such materials, you will find that some of the most common and ordinary things in daily life can be used to teach science very effectively. You will find many examples of such use of common materials in the boxed activities of this handbook. With practice you can learn to find and use many more.

(b) Take advantage of experts in the community. Although they may not have national fame, there are genuine experts in many fields in every community. There are successful farmers and good cooks; there are experienced merchants and skilful mechanics. Many parents are experts in some everyday field related to science—a field such as the making of thread and cloth, or the maintenance of carts and other farm tools. Nearby there are doctors, merchants, tailors and potters, health officers, district development officials, and the like. Take every opportunity to have such people come to your class or to have students seek them out and visit them where they work. In this way, children will not only learn the related science but will also learn much of value about their own community.

(c) Take full advantage of inexpensive

printed materials such as newspapers, magazines, and books.

(d) Consult the science teaching experts from the State Institute of Science or the State Institute of Education to get such help as you can. Most of these specialists are located in the state capital, but make frequent trips throughout the states. Write to them and seek their assistance.

(e) Contact extension centres for primary education and the teacher training colleges nearest to you. Each of these institutions has one or more experts in science teaching. Usually they can provide assistance if you specifically ask for it.

What is there to read?

Here is a selected bibliography of publications about science and science teaching. It is designed to include materials which are readily available and relatively inexpensive.

The teacher who earnestly seeks to improve his science teaching programme needs many kinds of help. Among other things, he needs books—books about science content, and books about ways to teaching science.

Many teachers in our country have difficulty in finding suitable books to help them teach science better. Although such books are not as plentiful as they should be, the situation is getting better. The list which follows includes books which are not only of great value to Primary School Science Teacher but also are apt to be available to him.

ENERGY AND WORK

1. BRANDWEIN. *A Sourcebook for the Physical Science*. New York: Harcourt, Brace & World.
2. DAS, L. G. *A New Matriculation Physics*. Allahabad : Indian Press.
3. N.S.T.A., U.S.A. *Investigating Science with Children—Energy in waves*. Darien, Conn, U.S.A. : Teachers Publishing Corporation.
4. TAYLOR, SHERWOOD. *General Science for Schools*. Heinemann.
5. UNESCO. *Unesco Sourcebook for Science Teaching*.

MATTER AND MATERIALS

1. BAHI AND PURI. *Modern School Chemistry*. Delhi : Gur Das Kapoor.
2. BARNARD AND EDWARDS. *The New Basic Science*. New York : The Macmillan Company.
3. BURNETT, JAFFE AND ZIM. *New World of Science*. Silver Burdett.
4. HARRISON. *Elementary General Science*. New York : Longmans.
5. LITTER. *A School Chemistry*. London : Bell.
6. PARSONS. *Everyday Science*. London : Macmillan.

GENERAL

1. Arey, C.A. *Science Experiments for Elementary Schools*. Bureau of Publications, Teachers College, Columbia University, New York.
2. Blough, Schwartz and Huggett. *Elementary School Science and how to Teach it*. Dryden Press, New York.
3. Joseph, E.D. *Teaching of Science in the Tropical Primary Schools*. Oxford University Press, London.
4. Little, W.B. *General Elementary Science*. Pitman and Sons, Ltd., London.
5. *Resource Materials Elementary Science*. Concordia Publishing House, St. Louis, Missouri.
6. Science Masters Association. *Report on Teaching of General Science*. John Murray, London.
7. *Unesco Source Book for Science Teaching* (available with prominent booksellers).
8. Verstraeten and Watts. *Science in Everyday Life*, Teaching Manual. Orient Longmans, Calcutta.

UNIT 4

ENERGY AND WORK

CLASS I

Overview

This unit deals with things which are mechanical in nature, with things that push and pull, with things that move, with things that are concerned with energy. In many ways it is one of the most fundamental of all the units in this syllabus. It is fundamental because it underlies so much of the rest of science. Forces are involved in air science and in sky science, and motion is involved in many areas of scientific study. All the areas of science, including the life sciences, are concerned with energy. It is for these reasons that the unit concerning forces, motion and energy is introduced to very young children at the class I level.

At this class level, children are introduced only to two concepts—distance and force. Children are familiar with the idea of distance. They think of distances as being large or small. Here they are introduced not only to familiar units of distance, but also to the familiar units of force.

The most common contact children have with force is in the case of weight, which is the force due to gravitation. This is the beginning for these very young children. From here they are also helped to understand that there are also other common sources of force, including the force developed in their own muscles.

On these simple but essential beginnings, these children will begin their understanding of force, motion, and energy. With these concepts they will better understand their own child-environment, as well as other areas of science they will be studying. Furthermore, they will be getting a sound foundation for a future understanding of the mechanical side of physical science, and for the all important concept of energy.

1. PEOPLE OFTEN NEED TO MEASURE DISTANCE

Measurement is concerned with questions such as 'how big' or 'how small'. It also deals with questions such as "to what extent or degree"—as when one speaks of the growth of a plant, growth of population or increase in hotness (temperature). Making measurements carefully and recording them accurately is a necessary part of learning science.

There are many things which can be measured: distance from one place to another; area of a surface such as a table top,

floor, or field; volume or space occupied by books, cloth, water or other objects; mass or amount of matter contained in an object; the time taken for a journey or a task; electric energy spent for lighting a house or cooking food, and so on. Measuring distance is the simplest of all measurements. It is useful to begin with distance when working with very young children.

1(a). DISTANCE MAY BE THOUGHT OF AS 'HOW LONG', 'HOW DEEP', ETC.

Children begin to acquire the idea of measurement quite early—earlier than many adults suspect. Small children may not be able to make accurate measurements. Certainly they cannot do any mathematical manipulations involving measurement. Yet they already have the general idea of 'how far'. They know that it is a short distance from their house to the school, but perhaps a long distance from their house to a relative who lives in another village. They know that some children are taller than others. They can tell the difference between a short stick and a long stick. Often they do not specifically realize that they are handling the concept of distance. Here are some activities which can help children grow in their understanding of the idea of distance.

Discussion — **How do we describe distance?**

Start with the floor of the class room or with the blackboard or a wall. Ask a student to point out the length, breadth and/or height. Similarly call upon individual students to show the height of a pupil, or the length of his arm. Call upon individual pupils to point out the perimeter of the room or the table, the distance around a student's head or chest or waist, the circumference (distance around) of a sphere or cylinder or pillar.

Ask a student to cut off just that length of thread required to pierce through ten apples or ten beads. Ask him to show the thickness of a finger or the head; these activities help children think in terms of distance.

Ask the students to count their steps on the way from school to home. Urge them to compare the result with the number of steps from home to the bazaar.

1(b). DISTANCE IS DESCRIBED IN FAMILIAR UNITS

Even though children have but a very crude concept of measurement, they have already become familiar with common units of measurement. They have learned about

these through their experiences at home, at school and at play. At home they may have heard their parents use terms such as mile and furlong and foot and inch. When they are playing they describe distances in such terms as 'steps' or 'arm's length'. At the bazaar they may have heard of units such as centimetre and metre. They may have heard of longer distances being measured in kilometres. Here are some activities which can help children recognize these familiar words and units of length.

Discussion | **How do we describe length?**

Ask children to estimate the length of a stick. Let them use whatever units they wish. Similarly let them estimate the height of the ceiling, or of a nearby tree. Ask a child how long it takes him to walk home. If he says 'ten minutes', that means a distance of 10 'one-minute walks'—really a unit of length. Let them use any non-standard unit to describe length, such as hand's breadth, foot-length, finger-width, etc. Among others, let them use metres and centimetres, too. Help them realize that there are many familiar units used to describe length.

Ask each child to estimate his height. Use a scale to check on their estimates. Express the height in centimetres.

2. FORCES ARE VERY COMMON; EVERYONE DEALS WITH FORCES EVERY DAY

There is no living human being who does not concern himself with forces many times each day. Often he is not aware of the force, or at least does not give it that name. But he does use his muscles to move himself and other things. He also uses forces provided by machinery and tools. But the force which is most familiar to all usually goes by another name. That name is *weight*. People weigh food and they weigh coal, they weigh metal and they weigh manure, they weigh seed and they weigh themselves. All of these weights with which children and adults are so familiar are really *forces*.

The sub-concepts below are concerned with helping children become more familiar with weight and its measurement. In particular, the sub-concepts are intended to help children realize that weight is really one example—a very common one—of a force.

2(a). OBJECTS HAVE THE PROPERTY OF WEIGHT

Every object has weight. When any one tries to move a big stone he feels its weight. When an object has much weight, it is said to be *heavy*. When water is pulled out of a well, one has to lift its weight. A large

bucket contains much water. Hence, it has more weight. Even air, which is not seen, has weight. Students will understand this better by handling some familiar objects, as in these activities.

Investigation

Do all objects have weight?

Materials required
assorted common objects

Collect a few common things, such as a book, a pencil, a rubber, a few stones of different sizes. Let a boy place an object in each of his hands and judge their weights. Different objects may have different weights. Help students realize that when one holds an object, his hands exert force. Through discussion, help them see the relationship between size and quantity.

Challenge children to name things which have no weight. Air has weight—so does the gas in a toy balloon or in a dirigible. 'Music', 'play', and 'happiness' are things which have no weight. However, these are not objects; they are not materials. All objects made of material have weight, even though it may be too small to notice.

2(b). COMMON MATERIALS ARE OFTEN DESCRIBED IN TERMS OF THEIR WEIGHT

It is very common to describe the quantity of a material in terms of its weight. Even very small children are aware of this. Food and other materials are often described in terms of their weight. The weight of a person is one means of describing how large he is. Children are aware of weights, but often fail to realize that weight is one way of describing the quantity of matter which an object contains. Here are some activities which can help children realize this.

Interview

What is the weight of common household materials?

Encourage children to ask their parents about the weight of common materials around the house. Let them ask their parents about the weight of a cow, or a can of milk. They can ask their father the weight of the seed he plants in the field. They can also ask shopkeepers about the cost of brass or iron or fertilizer. Answers to these questions will be in terms of cost for given quantity of weight of the material, such as rupees per kilogram. Discuss the results of these parent-interviews when the children return to class next day.

Help them realize that weight is a way of describing the quantity of material in an object or in a container.

Ask children to say what their weight is. If a weighing scale (weighing machine) is available, permit children to use it to see how much each child weighs.

2(c). WEIGHT CAN BE MEASURED WITH A PAN-BALANCE

Everybody has seen a pan-balance in a grocer's shop. A thing to be weighed is kept in one pan and the weights are added to the other pan until the bar of the balance shows a horizontal position. This is a common way to measure weights. When a thing is measured it is compared with a known weight. Thus unknown weights are measured in terms of known weights. Children can be helped to understand this better by actually weighing some common objects in a grocer's balance.

Investigation

How are materials weighed on a pan-balance?

Materials required
pan balance
objects to be weighed
set of weights

Borrow a common pan-balance from a merchant or from a parent who has one. Use it in class to weigh common materials like books, stones, food, and containers of liquid. In particular, help children note that the two arms of the balance are of equal length. When the arm is horizontal, the weighing is correct. Weight is determined by adding up the weights in one pan which just balance the material to be weighed in the other pan. Help children realize that this common method of weighing materials is really one of comparing an unknown weight with a set of known weights. See Fig. 4-1.

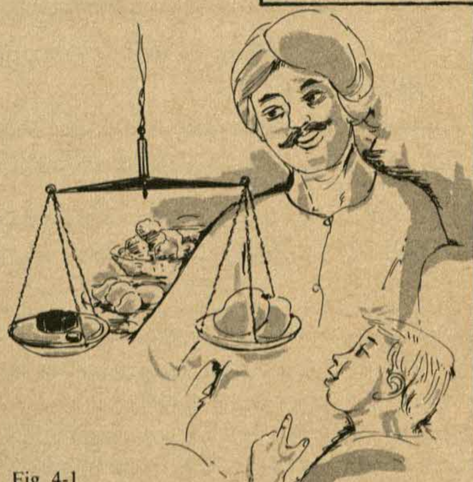


Fig. 4-1
Everyday weighing is a process of comparing the weight of an unknown quantity with that of an accepted standard.

Construction

Can we make a pan-balance?

Materials required
wood
string
cardboard
simple hand tools

Show children how it is possible to make a simple pan-balance from very ordinary materials, as shown in Fig. 4-2. First balance the long wood stick so that it is horizontal. Then make a small hole near the upper edge at this point of balance. Support the stick from a string through this hole. Use string on small pieces of cardboard to make the two pans for the balance. Notches or holes near the end of the long stick will help keep the pans from slipping off the ends. Use stones or seeds or lumps of clay of identical size for standard weights.

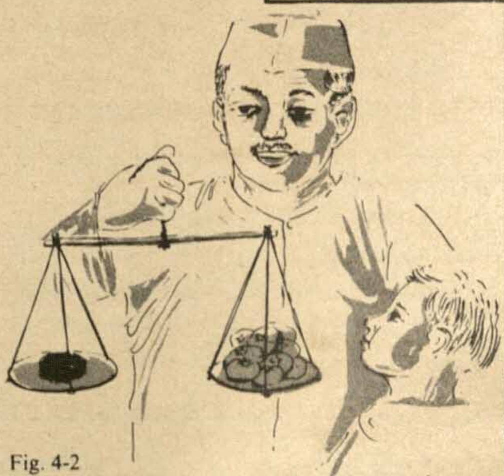


Fig. 4-2
It is easy to make a pan-balance from string, cardboard, and a stick.

Urge children to watch carefully how merchants weigh materials in the markets.

Challenge children to find ways of weighing things which do not involve a pan-balance. (Some may have seen a spring-type weighing scale.)

2(d). WEIGHT IS MEASURED IN FAMILIAR UNITS
When an object is weighed, it is really compared with the weight of some known object or objects. Thus, the units of weight are those of the *standard weights.* A few of the standard units of weight are already familiar to children from their daily-life experiences. They should be helped to realize that these standard weights are simply those which people agree to use for purposes of comparison. Here are some useful activities which can help children become familiar with common units of weight.

Demonstration

What units of weight are used in the local market?

Materials required
sample weights
from the market

Borrow some standard weights from the local market. These should be in units of kilograms, grams, etc. Let children examine these and try to estimate their weight by holding them in the hand. Let them use the weights as standards for a pan-balance. Point out to them that the weight of a group of these standards is simply the sum of their individual weights.

Interview

What standards of weight were used many years ago?

Encourage children to ask their parents or other adults about standards of weight used many years ago. They will find out about such units as maunds and seers and pounds and ounces. Help children understand that these units of weight are rapidly disappearing from use in our country.

Collect some 'ratti' seeds. Note how very uniform they are. Discuss how they could be (and once were) used as small standard units of weight.

For Better Understanding

For thousands of years before our independence, many different units of weight were used. These ranged from very simple standards, such as stones or seeds, to pounds, ounces, and tons. Soon after independence, however, our nation adopted the metric system as its standard for measurement. In this system, the standard unit of weight is that of the standard kilogram. This is also almost exactly the weight of one litre of pure water. Smaller objects are weighed in fractions of the kilogram. The most common of these fractions is the gram, which is one thousandth of a kilogram. For very small weights, the milligram, one thousandth of a gram, is used. For very large weights, a common standard is the metric tonne, which is equal to 1,000 kilograms.

Since the adoption of the metric system, the buying and selling of nearly all materials in any other units is illegal. In the use of the metric system, our nation joins most of the advanced countries of the world. Many of the English-speaking countries still do not use the metric system in everyday affairs. In terms of scientific units of weight, we are ahead of such countries.

3. THERE ARE MANY SOURCES OF FORCE

Class I children are already familiar with forces, because they encounter them every day. However, they seldom use the term 'force'. Instead they use such words as 'push', 'pull', 'tug', 'press', 'stretch', 'squeeze', and of course 'weight'. It is useful to help children realize that these are all examples of one thing: they are all examples of *force*. The particular word used depends on the direction in which the force is exerted, and for what purpose the force is applied.

Here is a case where words are relatively ineffective in helping children acquire a scientific concept. What is needed is not mere words, but more experiences to give meaning to words. There are many activities which can help children learn about the many sources of force that are around them every day. They can also be helped to realize that although the sources and the uses of various forces are different, all mechanical forces are fundamentally alike.

3(a). FORCE IS PRODUCED BY THE MUSCLES OF MAN AND OTHER ANIMALS

One of the sources of force most familiar to children is their own muscles. Force produced by people's legs makes it possible for them to walk and to climb. Children sometimes use the force of their muscles to play games. Adults use muscular force to move heavy things. If more force is required, man uses animals. The muscles of the animals can produce greater force than the muscles of man. Bullocks or water buffaloes or horses are used to pull heavy carts, draw water from wells, and plough fields. Here are some activities that will help the students understand that muscles are a source of force.

Investigation — **How can we move heavy objects?**

Challenge students to move a heavy stone, or a table or to lift one of their classmates. Have them note that a simple way to do this is with the force of their own muscles. Help them see how their muscles can produce forces often described as a *push* or a *pull* or a *squeeze* or a *lift*. Since all these 'kinds of forces' are produced by muscles, they must fundamentally be very much alike.

Field Observation — **How do we use the muscular force produced by animals?**

Take the class to the roadside or to the fields. Let them see how man uses the muscular force developed by cattle or camels or elephants or horses. Describe the efforts of these animals for the children in terms of force. Use phrases like 'force is applied' or 'exerts a force' frequently and correctly. Help children use the term 'force' to describe many kinds of mechanical actions.

Let the children organize a tug-of-war. Help them describe their activities in terms of the forces which they exert.

Let several boys unite to lift a heavy object. Describe their action in terms of the forces of their muscles overcoming the weight of the object.

3(b). PEOPLE USE MANY KINDS OF TOOLS TO HELP THEM EXERT FORCE

Depending on the type of task to be done, one sometimes requires a small force and sometimes a large force. Only a very small force is needed to lift a mango. However, a large force is needed to lift a truck wheel. To lift the wheel of a truck and change a tyre, one uses a jack. To dig a pit a spade is used. A crow-bar (stout bar) is used to move a heavy stone. Such tools help to exert the force according to the need.

A carpenter needs special kinds of tools. An iron-smith needs other kinds of tools. The iron-smith needs a heavier hammer than the one used by a carpenter. Here are some activities to help children see the many ways in which people use tools to help them exert force.

Investigation

How is a hammer useful?

Materials required
hammer
nails
piece of wood

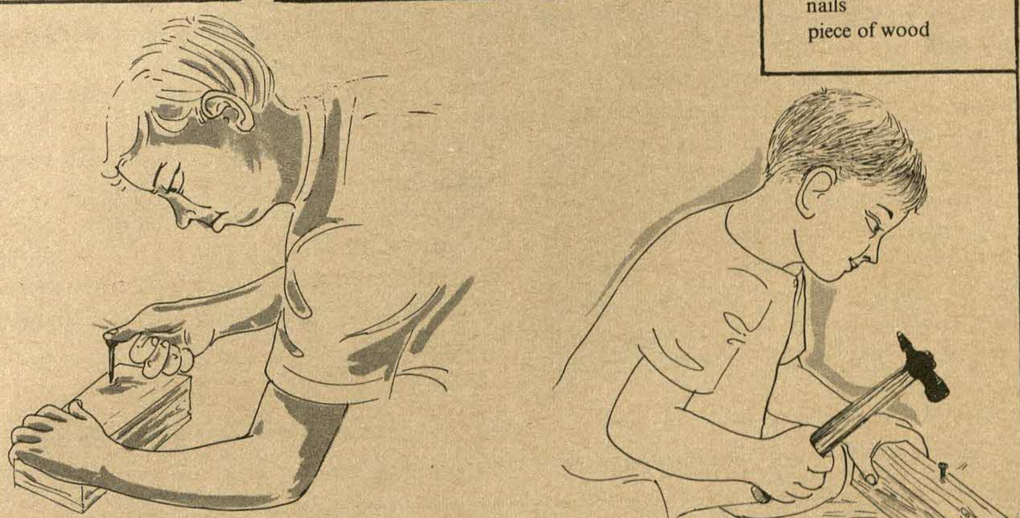


Fig. 4-3a, b
A hammer helps a person to exert enough force to drive a nail into wood.

Get a nail and a hammer. First ask one of the students to drive the nail into the wood by his hands as in Fig. 4-3. He is unable to do so. Then ask another student to use the hammer for driving the nail into the piece of wood. Help students realize that the hammer is a useful tool to help exert force.

Take students to the shop of the local iron-smith and let them observe how tools help the iron-smith.

Take your students out in the school garden and let them dig a pit with a spade.

Ask children to talk about tools used in their homes. Encourage them to bring tools and show other children how they are used.

For Better Understanding

As the term is used here, 'tools' are more than simply the devices which machinists and craftsmen use in their trade. Indeed, the term includes all the simple devices which permit the user to use his muscles to apply a force which is greater, or in a manner which is more convenient, or more safe than would otherwise be the case. In this sense, there are many many tools familiar to everyone. These include such common items as knives, brooms, shovels, scissors, jack-screws, saws, pulleys, needles, sugar-cane presses, and boat-oars, to mention only a few.

3(c). FORCE IS EXERTED BY STRETCHING OR BENDING

A stretched rubber band exerts a force as long as it remains stretched. As soon as it is released the force produces motion. A sling shot is a very good example of this. The spring of a clock is wound and then the clock runs until the spring is unwound. The bow which shoots the arrow is a bent strip of wood which exerts force. This force propels the arrow. Children can be helped to realize that force is exerted by a stretched rubber band or a spring through simple activities such as these.

Investigation | **How does a bow exert force on an arrow?**

Materials required
bamboo strips
string

Prepare a bow from a bamboo strip. Make an arrow from another strip. Let a student tie the two ends of the bamboo strip by a piece of string.

Let another boy shoot an arrow with the help of the bow. The bamboo strip bends and exerts force. When the arrow is released, it goes ahead. Then the strip takes its original shape. See Fig. 4-4.

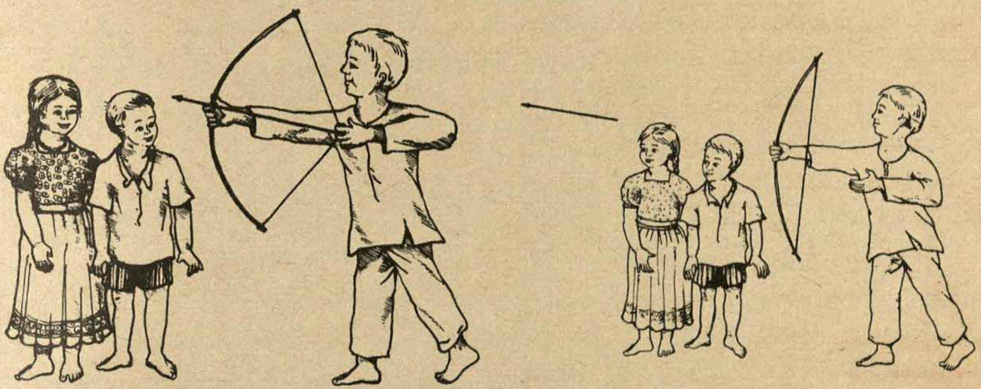


Fig. 4-4a, b
A bent bow exerts the force of an arrow; when the arrow is released, the force puts it in motion.

Let the boys prepare a sling shot using a 'Y'-shaped branch of wood and two pieces of rubber band.

3(d). MOVING OBJECTS EXERT FORCE WHEN THEY ARE SLOWED DOWN

When a child catches a ball, he slows down its motion. When the ball is slowed down, it exerts a force. The child can feel this force on his hands. Suppose a carpenter is driving a nail with a hammer. The moving hammer is slowed down by the nail. Very quickly the hammer comes to a complete stop. While the hammer is being slowed down, it exerts a force on the head of the nail. It is this force which drives the nail into the wood. If a small stone is laid on a piece of window glass, the glass does not break. The weight of the stone is too small to break the piece of glass. But if the same stone is *thrown* at the glass, the stone is slowed down when it strikes the glass. As it is slowed down, the stone exerts a force on the glass. Usually this force is great enough to break the glass.

Whenever any object is slowed down, it exerts a force. That is, moving objects are in themselves a source of force. All that is needed to use this force is to slow down the movement of the object. Here are some learning activities which can help children understand this principle.

Investigation

Does a moving child exert a force when he is slowed down?

Let a group of three or four children from a 'human wall', as in Fig. 4-5. Allow another child to run into this wall. The children in the wall are instructed to stop the running child. Does the running child exert a force as he is slowed down? Can the children in the 'human wall' feel the force which the moving child exerts as he is slowed down? Is the moving child a source of force? What is needed to use this force? (A way to slow down the moving child.)

Fig. 4-5
The running boy exerts a force when he is slowed down or stopped.

Investigation

How can a moving object exert force to break something?

Materials required
old earthen pot
small stone

Obtain an earthen pot which is to be discarded; it will be broken in this activity. Place a small stone on it. Help the children see that the weight of the stone is not enough to break the earthen pot. Now let a child drop or throw the stone in such a way that it strikes the earthen pot. The action should be strong enough to break the earthen pot. Does the stone get slowed down in its motion? Does it exert enough force to break the earthen pot?

Ask children how it feels to catch a ball, or a small stone, or large stone. Can they feel the force exerted by the moving object as they slow it down?

3(e). WEIGHT IS A FORCE

The earth exerts a force on each and every object. The earth pulls every object towards its centre. This pull of the earth is known as the force of gravity. It is difficult to lift a sack full of grain. It is easy to lift

a piece of fruit. Gravity pulls on the sack of grain more than it does on the piece of fruit. The sack of grain has more weight than the piece of fruit. A simple experiment will illustrate this.

Investigation

What force makes things fall?

Materials required
stone
string
scissors

Hang a small stone with a string. Tie the string to some hook or peg. Cut the string with scissors. The stone falls down. It is the force of gravity on the stone that pulled the stone down. The stone drops because of its weight.

Investigation

In what way is weight like a force?

Materials required
weights
pan-balance

Use a pan-balance or a spring-scale in the classroom. Let children use it to weigh objects. Have them use their arms and hands to push down the balance pan in the same way that something being weighed would push down on the pan, as in Fig. 4-6. Through discussion help them realize that the weight of the object being weighed is really a force which acts on the pan-balance.

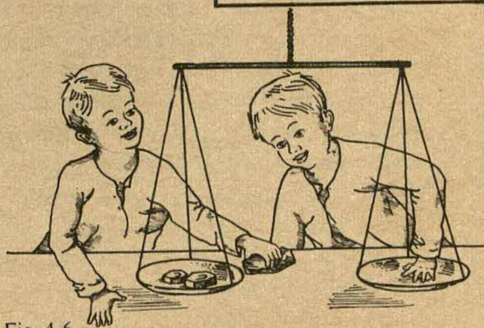


Fig. 4-6
A boy can push down on a pan-balance just as an object being weighed would push down.

Scientists at Work

What is the value of the idea of force?

Let us have a game—a contest. Suppose you are asked in what way all these things are alike: chapati, milk, curds, rice, lentils, and sugar. Who can give the answer first? The answer is that they are all foods. What is the value of this answer? The value is that all of those six things can be grouped together. Although they are different, they all do much the same thing. They satisfy you when you are hungry, they help you grow and be

strong. What about balls and dolls, and hoops and balloons? What do they have in common? They are all toys—all playthings. They can be grouped together even though they are of different sizes and shapes and colours and are made of different materials.

Can you think of other things which can be grouped together? What about various items of clothing? What about different animals which help us? What about different materials from which houses can be made? Do you see that different things can be grouped together because they serve the same purpose?

Now what does this have to do with what we have been learning about force? We have been learning about several different things—about how stretched rubber bands and bent springs work, and about how man uses tools. We have been seeing how muscles can produce forces, and how a moving object exerts a force when it is slowed down. We even learned that weight—so familiar to us all—is a force.

What we have been doing is grouping many different actions together because they all have something in common. All the things just mentioned are examples of *force*. What one of them can do, the others can do also. Since they are all forces, they can all speed up the motion of objects, or slow them down. And all these forces can change the shape of an object. Think about them once more:

forces from muscles
forces from tools
forces from rubber bands and springs
forces from objects being slowed down
weight

Can you think of ways in which each of these examples of a force can change the motion of an object? Do you agree that all these five examples can do the same things? Do you agree that they should all be considered as one thing, just as the chapatis and the curds etc. are all considered as one thing—food?

This, then, is the value of the idea of force. It brings together common actions and shows the way in which they are alike. Before you came to school you knew about stretched rubber bands and muscles and weight. But you did not know they are all sources of force, did you? Now you know more about all those five things in the list above—because you have grouped them all together as examples of force.

This is the way scientists often work. They study many things and try to group them together on the basis of what they have in common. Then the scientists understand *all* the things better. In this way, the study of science can help you to understand things better.

For Better Understanding

Under this concept there have been discussed five different sources of force: from animal muscles, from tools, from stretched or bent materials, from the slowing down of moving objects, and from gravitational attraction. There are also other sources of force, such as magnetic or electrical objects. It is important to realize that force is force, regard-

less of the source. It is also important to know that regardless of the word used—push, pull, stretch, attract, shove, etc.—it is still simply a force. Sometimes force is defined as a 'push or a pull'. This is not a very good definition, since it simply uses new words (push and pull) instead of the word being defined (force). It would really be much better to say that a force is that which can change the shape of an object, or which can slow down its motion or speed it up.

UNIT 4

ENERGY AND WORK

CLASS II

Overview

In class I students have been given an initial exposure to the ideas of measurement. They learned about the measurement of distance. They found that 'distance' has many names, and that units of distance are often familiar. They also learned about measuring the force of gravity, as when they weigh objects and materials.

Here in class II, children will have a chance to go farther with their understanding about distances. They have already learned what 'distance' means, and to describe it meaningfully. At this class level they begin the first step toward the actual measurement of distance—the careful comparison of one distance with another. Next these students are introduced to another quantitative concept—that of time. They learn to make comparison-measurements of time intervals, using their pulse, a simple pendulum, and eventually, clocks and watches.

Class I students have also been introduced to the concept of force. They have been learning to verbalize on what they already know about force through common experience. They learned that forces are produced by muscles, by stretched rubber bands and bent springs. They learned that people use simple tools to help them exert forces, and that forces are exerted by moving objects when they are slowed down. In particular, they learned that weight is force.

Now these children can go farther with their learning. They begin to see what people do to counteract force. In particular, they learn about overcoming (or counteracting) the force of gravity on (the weight of) objects. They learn that there are many ways of supporting the weight of an object. But if an object is to be supported, it is supported by the application of an upward force from some source or other. Thus, they learn not only to recognize a force, but also to control forces and to exert forces for useful purposes.

Thus by the end of class II, these children already have their earliest contacts with three important quantities and their measurement—the quantities of distance, time and force. They have already begun on this important step in understanding the physical world in which they live.

1. A DISTANCE CAN BE MEASURED BY COMPARING IT WITH A STANDARD DISTANCE

Distance is a quantitative idea. That is, some distances are greater than others.

That is, distances can be compared with other distances. Children know this from personal experience, even though they may not be able to express it clearly. They do have this concept, for they speak of one distance as being greater than another, or of one boy as being shorter than another.

1(a). DISTANCES CAN BE COMPARED WITH ONE ANOTHER

Students are familiar with the distance between home and school, between one village and another, and between a nearby town and a village. They are also able to understand the difference between the distance along a straight road and the distance along a curved road—that the latter is greater than the former. Help them realize that distances can be compared through activities such as these.

Discussion

What is meant by terms such as 'farther', 'taller', 'longer', etc.?

Engage students in a discussion about relative distances. Ask them which is greater, one dimension of the room or the other. Which is farther—from the school to the road or from the school to a certain well-known tree? Who among the children lives the farthest from school? Who lives the nearest? Who is the tallest child in the class? Who is the shortest? Who has the longest foot? Who can reach farthest from fingertip of one hand to fingertip of the other? In discussing these, help the children realize that they are comparing distances.

Ask students to tell the shortest of three or more routes to a certain place from the school. Ask them how they arrived at their decision.

1(b). THE METRE IS THE ACCEPTED STANDARD OF DISTANCE

The fact that one distance can be compared with another is the basis for measurement of distance. In measurement of distance, one compares an unknown distance with one which is known. Children do this very naturally. They compare the distance to a certain place with some familiar distance, such as the distance from school to home, or from their plot of land to the bazaar. Or they compare the height of another person with their own height. This is a simple but scientific way of measuring distance. What is required for the best of measurements, however, is a standard unit which is acceptable to all people. In this country as well as in most other countries of the world, this standard distance is the *metre*.

Children need help in seeing that a standard distance is really necessary for good measurements of distance. They also need help in recognizing the metre as such a standard. Here are activities which can help teachers to make these points clearer to children.

Class Project

Of what use is a standard unit of distance?

Materials required
short stick

Invite the class to agree on a short stick as a standard unit of length. The stick's length might be about half a student's height. Help the children get the idea that any ordinary distance can be compared to this. Thus, a tall child might be two sticks high, or the room might be 30 sticks wide and 40 sticks long. Help the students make measurements such as these by counting the number of stick-lengths which go into a room-length or a room-width, as in Fig. 4-7. Now use the same method to measure the length of another room. Perhaps it is 36 'sticks' long. Now help children to see how they can compare the lengths of the two rooms, even though they cannot put the two rooms side by side for a direct comparison. This illustrates the value of a standard unit of length. Two people could measure the width of their kitchens in two different villages, provided they agreed on the standard unit of length with which to do the measuring. Emphasize the fact that people must agree on a standard unit of length if the unit is to be of any value.

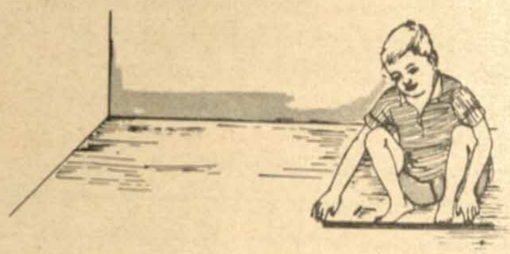


Fig. 4-7
The length of the room can be measured by seeing how many stick-lengths go into it.

Demonstration

How long is a metre?

Materials required
metre scale or
stick one metre long

Show the children a metre scale—or a stick of wood cut to the length of one metre. Ask them if there is any reason why this should not be used as a standard unit of length. It is, after all, a convenient length for measuring ordinary distances. Point out that this unit has been accepted as a distance standard throughout the world. Use the stick to measure the length of the room, the height of a child or the distance to the road. Show the children how the metre is divided up into 100 equal parts. Each of these is called a *centimetre* (literally, 1/100 of a metre). The centimetre is a useful standard unit for measuring small distances.

Investigation

Is an arm's length a good standard for distance?

Ask a student to measure the length of the room or table by using his cubit (the distance from the elbow to the tip of the stretched middle finger) as in Fig. 4-8. Note this length on the board as so many cubits and a fraction thereof, if any. Ask another student—taller or shorter than the first one, chosen by you—to measure the same length in terms of 'his cubit'. Record this also. The teacher should measure the same length in terms of 'his cubit'. Record this also. Ask why the figures differ even though they are measuring the length in the same way and the same name 'cubit' is used. Help them realize that the cubit is not the same length in all persons.

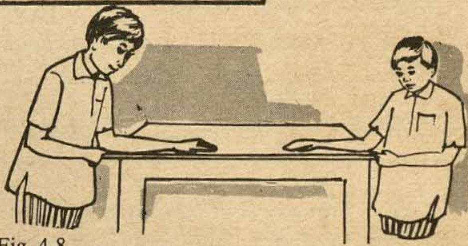


Fig. 4-8
The length of the forearm is not a good standard for measuring distance; it differs from person to person.

Ask a pupil to use the length of his foot as a unit to measure the length of a wall or table. Ask two or more students of different sizes to do the same and discuss why there is confusion. See Fig. 4-9.

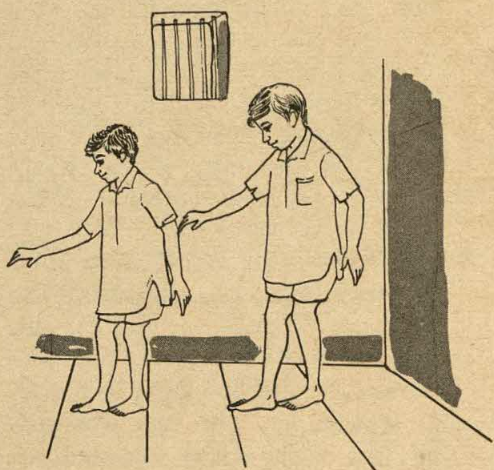


Fig. 4-9
The length of a person's foot is often used as a standard of measurement. However, it is a poor standard because the feet of different persons are of different length.

Ask children to note how the cloth merchant and the rope seller and the lumber man measure their products in terms of metres. Point out that it is illegal to buy or sell such materials in our country in any other units than those related to the metre.

Help children to make small measuring sticks of their own. This can be done simply by marking off a straight clean stick in units of centimetres.

Scientists at Work

Our country uses the metric system

Let's pretend! Let's pretend that you are the headman—the leader—in your village. There are complaints from the market-place. Some people are saying that they have been cheated in the things they buy. One man thought he bought enough rope to lower a bucket into his well, but when he got home there wasn't enough. Two women bought saris but the saris were too short. The village paid for having a section of roadway made smooth and covered with rock. But most of the people think the workmen fixed a shorter section than they were paid to fix. As headman of the village council, you have problems. What would you do about them?

You really want to find out what the trouble is. So you go to the market and investigate. Perhaps you find that the rope merchant is measuring rope with a worn out yardstick given to him by his grandfather. The man who sells the sari cloth simply measures its length with his outstretched arm. And the men who repair the road—they step it off to see how much they should work on. *Now* what would you do about the problem?

Surely one good way would be to get people to use good standards for length, not worn out measuring sticks or arms' lengths, or paces, or good estimates. Also, it would be fine if everyone in the village used the *same* standard for measuring length. If this is the way you want it done, what should be used as a standard of length?

Well, you might find out what nearby villages are using. Perhaps the district or even the state where you live has adopted some standard for length. It would be very practical if you could use the same length standard that other communities use.

This is the kind of situation our country found itself in when we won our Independence, over 20 years ago. Many units of length were in use—feet and inches, furlongs and fathoms, paces and days' travel. So the people in the government looked to other nations of the world to see what standards of measurement were being used. They found that the most common one—and by far the most useful system—is the *metric system*, developed in France more than 150 years ago. It is the system used by scientists all over the world. Most of the nations use this metric system entirely. So naturally our nation decided to make

it official too. That is why it is now against the law to buy and sell materials in maunds or chataks or inches or pounds. We use the metric system entirely. The metre is the standard of length.

In our use of the metric system, we are ahead of some of the most modern nations of the world. In England, the United States and some other English-speaking countries, the metric system is used in science laboratories and is the legal standard for length. But in daily use, distances are measured in the clumsy, old-fashioned units of inches and feet, yards and miles.

But in our nation, we use the metric system!

2. PEOPLE OFTEN NEED TO MEASURE TIME

Before they are even old enough to go to school, children are aware of the concept of time. They use the word time in asking what time it is—or if it is time to eat. They make wide use of the concepts of 'before', 'after', 'late', 'early', 'soon', 'at the same time', 'when' and 'just now'. Some children use 'minutes' and 'hours' correctly, and a few can tell time by the clock. In this unit, the teacher should try to build upon this knowledge which students already have, and to improve it and organize it. In addition, children can now be introduced to the simplest ways of measuring time.

2(a). TIME CAN BE THOUGHT OF AS 'HOW LONG', 'HOW LATE', 'WHEN', ETC.

Small children are experienced in using the basic concept of time. They know very well which of two observed events happens first. They know that night follows day, and after night comes another day. They know that some events last for a long period, while others are completed very quickly.

The teacher's role at this class level is not so much to introduce these ideas—which really need no introduction—but to bring them together. Children need help in realizing that their present scattered bits of information are really all related to one physical concept—the passage of time. Activities such as the following will be helpful in making children aware of what they already know about time.

Demonstration | **What is an interval of time?**

Ask all the children to close their eyes while the teacher counts aloud to ten. During that interval the teacher should move something inside the room. Perhaps the teacher can walk quietly from one place to another, or move a chair or a table, or open or close a window. Children should be then challenged to say what has happened while their eyes were closed. Help them realize that their eyes were closed while some time passed. Their eyes were closed

long enough for a change to occur in the room. Something *happened* while their eyes were closed. Their eyes were closed for a *period* of time. Their eyes were closed for an *interval* of time.

Raise one hand, then the other. Ask children to state which hand was raised first, which later. Point out to them that they are really comparing the occurrence of events in time.

Teach children to clap their hands or tap their feet in time to music. Help them realize that with the claps or the taps they are really measuring off equal intervals of time.

For Better Understanding

There are two different meanings to the noun 'time'. Children in class II cannot be expected to distinguish clearly between the two meanings. However, the difference is interesting and important for the teacher. One meaning of 'time' is implied in the phrase 'at what instant'. That is, 'time' may be thought of as a *point* in the passage of events. This is the sense in which the word is used when one asks, 'At what time...?' The answer might be: 'At exactly 3.30' or 'Just at sunrise'.

On the other hand, the term 'time' sometimes applies to a 'time interval'. This is the meaning when one asks for the time required to cook potatoes, or to run 100 metres. Here the answer is in terms of a *duration* of time—'The bread can be baked in 45 minutes', or 'Ten seconds is excellent time for the 100 metre dash.'

2(b). TIME IS DESCRIBED IN FAMILIAR UNITS

The units in which time is described are almost the same in all parts of the world. Very small time intervals are discussed in terms of seconds and minutes. Longer intervals are described in terms of hours or days or weeks. Very long intervals are discussed in terms of months, years, decades, or centuries.

In the beginning, man measured time only in days and large fractions of a day. Gradually he measured time in hours with the help of an hour glass, a sundial, etc. Then he divided an hour into 60 minutes and a minute into 60 seconds.

Help children to understand the interval of a second, a minute and an hour through the following activities.

Discussion

How old are we?

Ask children to say how old they are. They will answer in terms of a certain number of years. Tell them approximately how old the school building is, or a prominent tree with which they are all familiar. Point out that when one talks about the age of a person or thing, he is really talking about a time interval since that person or thing started to exist. Ask them how long it has been since the month began, or since school began on this very day. Again point out that they are discussing time intervals since something began. Also help them realize that they are describing time in terms of accepted units of interval—units like year, day, and hour.

Demonstration

How long is a second?

Materials required
measuring tape
stone

Tell children you are going to demonstrate exactly how long an interval of one second is—without a watch or a clock. Select a position (like out of a window or from a tree or a roof) which is 4.9 metres above the ground. Drop a stone through this distance. The time interval during which the stone falls is one second. If such a height is not available, demonstrate the duration of one half second. This can be done by similarly dropping a stone through a distance of 122.5 centimetres, as in Fig. 4-10.

Fig. 4-10
A stone released from rest falls 122.5 centimetres in one half second.

Have children close their eyes, then raise their hands when they think an interval of 10 seconds, or one minute, has passed. When the desired time has passed, signal them to open their eyes. How well have they estimated the time interval?

For Better Understanding

Time is measured all over the world in the same unit—the second and its multiples. Time is also measured in weeks; every one knows this—it too is the same all over the world. But the meaning of month is not the same everywhere.

One lunar month is about $29\frac{1}{2}$ days; it needs correction to fit in with the solar calendar. Some communities (for instance Muslims) do not apply this correction at all even to this day and follow the lunar calendar for religious purposes.

2(c). TIME IS OFTEN MEASURED WITH CLOCKS AND WATCHES

Watches and clocks are by far the most common devices for the measurement of small and medium intervals of time. Ordinary watches measure in units of hours and minutes and sometimes seconds. Occasionally a fine wrist watch also shows time in units of days. Most clocks indicate time only in terms of hours and minutes.

Children at the class II level are sometimes able to read the time on clocks and watches. If some in the class cannot, this is a good time for them to learn. Here are some activities which can help to familiarize children with clocks and watches.

Demonstration

What are the divisions on the face of a clock?

Materials required
clock or watch

Show a watch to the students. Ask them to point out the hour hand, the minute hand, and the second hand. Let them count the divisions between any two hour marks. Ask them what they find. Ask them to count the total number of divisions on the dial. What time interval does each division measure? Help children to understand that for every complete revolution of the second hand, the minute hand moves only one division. What does this indicate? For every complete revolution of the minute hand of a clock the hour hand moves 5 divisions. What does this indicate?

Demonstrate to children how a clock or a watch is wound. Point out that the wound-up spring is what makes the timepiece keep going. Let children listen to the ticking of a wrist watch. Almost all men's size wrist watches tick five times per second.

2(d). TIME CAN BE MEASURED WITH THE PULSE, WITH A PENDULUM OR BY OTHER SIMPLE MEANS

Although short and medium time intervals are most commonly measured with clocks and watches, there are many other simple and reasonably good ways to make such measurements. It was less than 400 years

ago that the most primitive mechanical clock was built. Throughout the past, time has been measured with such devices as sun-dials, hour glasses, candles, and water clocks. No one knows how long ago the first man made crude measurements of time using his pulse. It is interesting for children to learn about some of these earlier methods of measuring time and to work with them. Here are some activities through which children can have such experiences.

Investigation

How can we measure time with our own pulse?

Ask the children to place their fingers on their wrist as in Fig. 4-11. Help them find the proper place to feel their pulse. Encourage them to count the number of pulse-beats in one minute. Record on the blackboard the pulse-rate as reported by a few students. Ask them to mention a few difficulties which are involved in using the pulse to measure time.

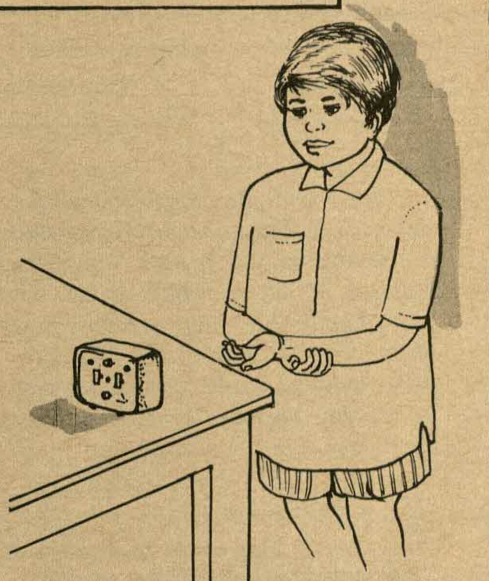


Fig. 4-11
The pulse is sometimes useful as a method of measuring time. However, the pulse-rate is not constant.

Investigation

Does the time for a pendulum swing remain constant?

Materials required
string
stone
watch

Tie a stone to a piece of string. Tie the other end to some support such as a nail driven into the wall. Make this simple pendulum swing through a small angle. Ask the pupils to count the swings. Note the time taken for 20 swings, using a watch which has a second hand. Change the amplitude and repeat the experiment. Help the students to understand that the extent of swing has almost nothing to do with the time of swing.

Repeat the above—using strings of different lengths. Does the time for a complete swing of the pendulum change as the pendulum length changes?

Show the students a sun-dial. Help them to know how it measures time during a large portion of the day when it is properly placed.

Demonstration

How does a water clock work?

Punch a small hole in the bottom of a tin can. Fill the can with water so that it will drip as in Fig. 4-12. Count the number of drops which come out each minute. Show the students how water drips at almost equal intervals. What happens to the rate of dripping as the can becomes more and more empty?

Fig. 4-12
Water dripping from a small hole provides a useful method for measuring time intervals.

Show students how a sand glass (hour glass) works. Ask the students to tell the defects in using this to measure time. If you do not have a sand glass, pour sand in a funnel and show how sand drips at a steady rate.

For Better Understanding

Many children are familiar with the words day, month, year etc. The day is measured between one noon and the next noon. It is noon when the sun is exactly midway between

the east and west horizon—i.e., nearest to being directly overhead. The day is a natural unit of time. The day can also be defined as the time taken by the earth to go round on its axis once, using the sun as a reference point. This is called the *solar day*.

The time taken by the earth to go round the sun once is called a year. One year is found to be equal to almost $365\frac{1}{4}$ days. The year is divided into 12 months in the Indian National Calendar. Some months have 30 days, some have 31.

Time is also measured by the motion of the moon with reference to the earth. The time from one new moon to the next new moon is the *lunar month*. It is just a little more than $29\frac{1}{2}$ days. Twelve lunar months make one year in the lunar calendar. The lunar year is shorter than the solar year. Hence once in 2 or 3 years an extra month is added to the lunar year.

Nearly all primitive societies have used both a solar calendar and a lunar calendar. Both may be thought of as 'natural calendars.' Unfortunately, there is no simple relation between these two kinds of calendars. Modern peoples throughout the world conduct their governments and their business on a solar calendar. For such purposes, all that remains of the lunar calendar is the length of the modern month, which is quite close to $29\frac{1}{2}$ days. In our country and some others, however, the lunar calendar remains, at least in part, the basis for religious events and traditional holidays.

3. THERE ARE MANY WAYS OF SUPPORTING THE WEIGHT OF OBJECTS

Long before they get to school, small children know that familiar objects have weight. While they may not speak in learned terms about the force of gravity, they do describe objects as being 'heavy' or 'light'. In class I they have learned that weight is a force.

Small children also know what they must do to overcome or counteract the weight of an object. They must lift it or hold it up somehow. They may support an object by resting it on a table or by hanging it on a hook. Although they may not realize it, they are counteracting the force of gravity (which is downward in direction) with force, upward in direction.

In presenting this major concept, the teacher should take advantage of the common, everyday knowledge which children have gained from their own experience. Working on this basis, children can be helped to understand that the weight of objects can be supported (counteracted) by an upward force.

3(a). OBJECTS FALL UNLESS THEIR WEIGHT IS SUPPORTED

Every child has seen fruits hanging from trees. It is also common to see fruits falling from a tree. Why does one mango or nut hang, while another falls? In everyday terms, one hangs there because it is held up by the stem the other falls because the stem is too weak to hold it. Children have often seen raindrops falling from the sky. When raindrops are formed high in the air, there may be nothing to support their weight. Therefore, they fall. Any object will fall unless it has something to support its weight. Students will understand this better if they see unsupported things fall.

Investigation	Why do some stones fall?	*Materials required* two similar stones

Hold two stones of approximately the same size in two hands, one touching the surface of a table and the other just beyond the edge of the table. Let them go simultaneously. The stone supported by the table remains on the table. The other stone falls down. See Fig. 4-13.

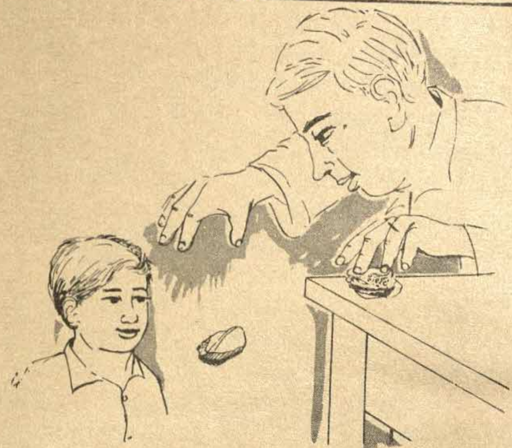


Fig. 4-13
The stone at left has no support from the hand or from the table; it falls. The stone at right has been released by the hand, but it is supported by the table.

Let the students observe how the roof of a house is supported.
Let them watch when a rolling marble falls down from the edge of a table.

3(b). OBJECTS CAN BE SUPPORTED BY PUSHING UP ON THEM

The children have now seen how a table supports a stone. In Fig. 4-13 the stone not supported by the table is shown falling to the ground. Then it remained on the ground. Why? It does so because the floor supports its weight. Objects can also be supported by the strength of muscles. A camel or an elephant supports a heavy load with its muscles, even if it is standing still. The animal pushes up on its load. When a workman is loading a cart with heavy sacks he is pushing up on the sacks, one at a time. He is supporting the weight of the sack until he places it in the cart. The following activities will help students understand this principle.

Investigation	When do muscles provide a push?	*Materials required* medium-sized stone

Secure a stone which is heavy, but not too heavy for a child to hold. Let a child hold it at least as high as his head. Ask him what muscles are sup-

porting the stone. Is he really pushing upward on the stone? What happens if he stops pushing up on the stone? Help the class see that the child's upward push is what supports the stone—keeps it from falling.

Permit a child to crawl under a small table and support it by pushing it up. Help him and his classmates realize that the child's push is keeping the table from falling.

3(c). OBJECTS CAN BE SUPPORTED BY PULLING UP ON THEM

Children have now seen that objects will fall unless their weight is supported in some way. They have also seen that one way of supporting the weight of an object is to push upward on it with the muscles. Another common way is to *pull* up on it with the muscles. Children do this so frequently that it is difficult to have them analyze the situation. Here are some activities which will help them analyse the supporting of objects by a pull of the muscles.

Investigation

How does a pull support the weight of an object?

Materials required
stone
string

Tie a stout string around a stone. Select a child and have him lift up on the string until the stone is hanging away from the floor. Help the class to discuss this in terms of 'pull'. Is the string pulling on the stone? Is the student pulling on the string? Is the student exerting a pull with his muscles? What happens if the string is cut? It can no longer exert the pull. What happens to the stone if the child stops pulling? Help the class to see that the stone's weight is being supported (counteracted) by an upward pull.

Permit a child to support himself by hanging with his hands. What is the source of pull which supports his weight? Can he feel the pull in his muscles?

For Better Understanding

Adults immediately see that a push and a pull are fundamentally the same thing. The only difference is that a push is usually *away from* the person involved, while a pull is *toward* him. Excepting for the position of the body, the muscles do much the same

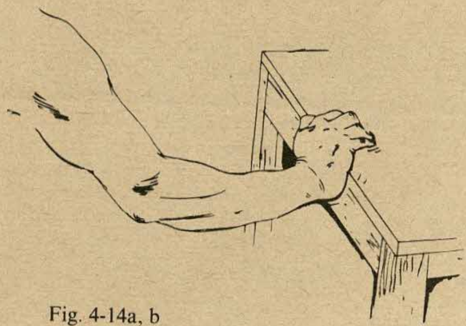
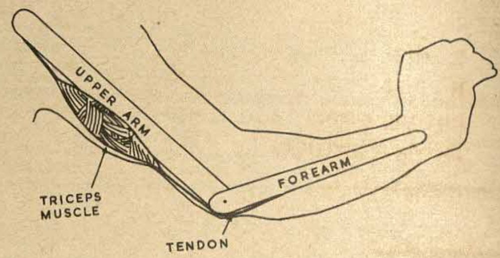


Fig. 4-14a, b
Although muscles can only pull, people can push, as when one pushes against a table with his hand.



The lower view suggests how the pull of the triceps muscle is converted to a push at the forearm. (The bones are shown as straight rods for simplicity.)

job whether a person exerts a push or a pull. Actually, muscles cannot literally *push*, anyhow. When they contract, they *pull*. The mechanism of the body (levers made up of bones and joints of bones) convert this pull into a push away from the body. See Fig. 4-14.

In the final analysis, a pull or a push to support an object is the same as having the object supported by a table or by the floor. In one case, the support is supplied by muscular tension; in the other, by the strength of wood or of stone. When an object is supported by a push or a pull, the person whose muscles are involved may become tired and sore. A table or a chair does not become tired or sore by supporting an object. Neither does a person, under the proper conditions. For example, a boy in a crouched position, supporting a book on his knees, uses no muscles to support the book. He may become weary of his squatting position, but his muscles do not become fatigued supporting the book. The book is supported by the strength of his bones, just as the book might be supported on a table by the strength of the wood in the table.

3(d). FLOATING OBJECTS ARE SUPPORTED BY WATER

An object on the floor or on a table or hanging on a hook is supported by the floor or by the table or by the hook. When a person supports an object, he does it with a push or a pull, usually developed by his muscles. What of an object floating in water? What supports it? Does it have weight when it is floating? Many people say that a floating object has no weight. This is not true. A floating object is supported by the water, much as another object is supported by the floor or by a table or by muscles. Here are some learning activities which can help children understand this principle.

Investigation | **What supports a floating object?**

Materials required
bucket
water
stone
piece of wood

Fill a bucket with water. Obtain a piece of wood and a stone of approximately the same size. Place the wood piece on the surface of the water and

let the children see that it floats. When it floats the water supports it. Now put the stone on the surface of water. It sinks because the support of water is too small to hold the stone's weight. It is something like dropping an object which is too heavy to be held in the hands.

Float two regular blocks of wood of the same size but of different weights. One sinks deeper than the other.

Push a piece of wood under water; remove your hands. It shoots up. Why?

3(e). THE WEIGHT OF AN OBJECT CAN BE SUPPORTED BY AN UPWARD FORCE

This sub-concept is really a way of summing up the four sub-concepts which have gone before. Adults know that all the ways of supporting an object can be described by saying that an object can be supported by a suitable upward force. The arrangement of ideas on these pages is intended to help children arrive at this conclusion on the basis of existing knowledge and their own first-hand evidence. It is the teacher's task to help students see that 'supporting an object' means 'applying an upward force to counter-balance the object's weight'. Here are some activities to help the teacher in this task.

Discussion | **What is the relation between 'support' and 'force'?**

Ask children to look back on the activities involved in the four preceding sub-concepts. What is there that they all have in common? They all describe some means for supporting the weight of an object. The means are supplied by a table, by muscles, or by the water in which some objects float. Help the children to use the discussion to explore what it is that supplies the support. Is there another word for support in uses such as these? Is there one word which can be used in place of support, push, and pull? The word is *force*. This is not a new word for the children. In class I they have learned that force is exerted by muscles and wood and stretched springs, among other things. Help them describe all the foregoing activities using the words 'exert force' rather than 'supply support'.

Investigation

Does water exert a force on a floating object?

Materials required
bucket
water
football

Permit a student to try to push a football or a large balloon under water as in Fig. 4-15. He will agree that some push (force) is required. Help the class realize that the downward push required really overcomes the upward push of the water. This upward force is what provides the support for a floating object.

Fig. 4-15
Water exerts an upward force on the football being pushed down into it.

Suspend a stone on a stretched rubber band. Remind children that a stretched rubber band exerts a force (learned in class I). Help them see that the 'pull' of the stretched rubber band is really the force exerted by the stretched rubber band.

For Better Understanding

In adult terms, this entire major concept can be summarized very briefly, thus:

Weight is a force, it acts downward.

To support a weight, supply an equal force, upward in direction.

Children in class II now have all the necessary parts of this brief but useful generalization. They know from class I that weight is a force. Now they learn that different ways of providing support for an object are really just different ways of supplying an upward force to counteract the downward force (the weight).

If the upward force on an object is exactly equal to the weight of the object, it neither rises nor descends. The two forces are exactly equal and opposite. If one wishes not simply to *support* an object, but to *lift* it, he must supply an upward force slightly greater than the weight of the object.

Any object which has weight falls if it is not supported by some suitable force. An object supported on a table does not fall because the table exerts an upward force equal to the weight of the object. When an object floats, it is because the water exerts an upward force on the object equal to the weight of the object. The same is true of a gas balloon. The balloon has weight, although not very much. Its weight is typically less than that of the same volume of air. The air pushes up on the balloon just as the water pushes up on a floating object. Usually the upward force of the air is greater than the weight of the gas-filled balloon. As a result, the balloon rises, unless it is held down by an additional downward force (pull) of a string.

UNIT 4

ENERGY AND WORK

CLASS III

Overview

In this unit students are acquiring an understanding of some of the most fundamental concepts of science. They are having meaningful experiences with force and motion, with time and distance, with energy and the control of energy. These fundamental concepts underlie much of the understanding of the universe, both in its physical and biological aspects. These concepts also contribute to the understanding of many of the other units in primary school science. For this reason, this is one of the most important units of work in the science education of young children.

In classes I and II children have learned about force in different forms and under different names. They have learned that weight is really a force, and that the weight of an object can be supported by an upward force; this may be provided in many ways. They have also learned about two other kinds of measurements—of distance and of time. They have learned that in these two kinds of measurements, what is involved is really a *comparison* of distance or time with some standard interval of distance or of time.

Here in class III, children apply this same logic to the measurement of force. They learn about the metric standard of force—the legal standard in this nation. They also can apply their growing knowledge of force to situations involving friction. They learn of ways to reduce friction when it is undesirable, and of increasing friction when it is desirable.

In class III students encounter the all-important concept of a force being applied through a distance. This leads them into an informal introduction to the concept of work. Children will learn to identify this with energy, and thus be off to a good start to understanding one of the most fundamental concepts in all of science. They will also be introduced to simple machines—those devices which people so often use to help them do physical work.

Finally, children at this class level will learn about two more kinds of simple measurements. One of these—the measurement of area, is an extension of the concept of measurement of distance. The other is something with which they have already had informal contact—the measurement of temperature.

The teacher's task here is not so much to introduce new materials. Rather, it is to build upon the everyday informal experiences which typical children have already had—to help them to understand experience in

simple physical terms, to help them to build a solid foundation of concepts and measurements which contribute to an understanding of many of the fields of science.

1. FORCES CAN BE COMPARED WITH ONE ANOTHER

In earlier classes, children have been exposed to the idea that there are many sources of force, and that one of these is the weight of an object. They are also familiar with the process of weighing, and know that it is really a process of comparing the weight of an unknown object with that of a known one. In their earlier experiences with weighing, they have encountered the notion of standards of weight. They have come into contact with familiar local units of weight, and also with the kilogram.

However, these are understandings which really come only with repeated and extended experience. Accordingly, it is in order to treat them at a more mature level here in class III. Here they are treated not so much in terms of *weight*, but in terms of the more general and more useful concept of *force*. Also the idea of measuring force by a spring balance is introduced in this major concept.

1(a). FORCES CAN BE COMPARED WITH ONE ANOTHER

Children have already learned to compare weights. They have done this simply with subjective judgements as they handle objects with their own hands. They have also seen weights compared by merchants using pan-balances, and they have carried out such weight comparisons themselves. However, they need some review on this, and they need help in generalizing from the specific concept of weight to the more general one of force. Here are some experiences which can help children become more familiar with the process of comparing forces.

Investigation

Can we compare forces with our hands only?

Materials required
rubber bands

Arrange two sets of stretched rubber bands as shown in the Fig. 4-16. Permit a student to pull on the single rubber band with one hand, and on the group of rubber bands with the other. Could he tell which hand encounters the greater force without looking at the sources of the force? What difference is there between this comparison of forces and the comparison of weights a person makes when holding two objects, one in each hand ? (Fundamentally, there is no difference).

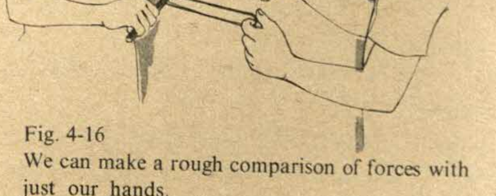


Fig. 4-16
We can make a rough comparison of forces with just our hands.

Discussion

What are some common sources of force?

Engage students in a discussion of familiar sources of large and small forces. Many of the sources they suggest will be weights. Help them also to suggest some which are not, such as the force exerted by bullocks or horses as they draw carts, the force exerted by wind, the force exerted by a stretched or bent spring, or the force exerted by petrol engines or electric motors.

Let children feel with their own muscles the forces which other children can produce with their muscles.

Permit children to organize a tug-of-war. Help them realize that they are really comparing the forces of the two opposing teams. The team which wins does so because it exerts a larger force than the losing team.

1(b). THE WEIGHT OF A KILOGRAM IS AN ACCEPTED STANDARD OF FORCE

Children have in earlier classes learned about the kilogram as a standard unit of *weight*. In this class, the same general idea—and the same kilogram unit—is used as the basis for the standard unit of *force*. The task of the teacher here is to review what the children already know, and to help them broaden the concept from one concerning weight to one concerning the more general notion of force. Here are some activities which can help the students in this increased understanding.

Investigation

How can we measure the force produced by our muscles?

Materials required
simple pan balance
one kilogram weight
container which holds more than a litre of water

Set up a simple pan-balance to weigh a container of water as in Fig. 4-17. Put in just enough water so that the container and the water weigh one kilogram. Or this can be done with a bag of sand or any other convenient

arrangement which can be adjusted to a weight of one kilogram. Review with the children that the weight of water (or sand) and that of the kilogram-weight are the same. They are really comparing the weights of the materials in the two balance pans. Remind them that weight is a force, so really they are comparing two forces. Now challenge them to say how it is possible to balance a weight force against a force produced by muscles. Help them to develop the idea that when they start to lift a weight, their muscles are producing a force slightly greater than that weight. Thus, if a child lifts one kilogram of weight, or 12 kilograms of weight, he is producing a force of one or twelve kilograms, as the case may be.

Fig. 4-17
We can compare forces accurately with a simple pan-balance.

Discuss the sports competition of weightlifting. Point out that when the competing athletes try to lift larger and larger weights, they are really demonstrating their ability to produce larger and larger forces with their muscles.

Point out that when a person climbs a ladder or a rope, his muscles are exerting a force big enough to counteract his own weight.

1(c). A FORCE CAN BE MEASURED WITH A SPRING SCALE

Although pan-balances are simple and useful devices for measuring weight, they are not the only ones. Force—including weight—can stretch a coiled spring. The greater the force, the more the spring is stretched. If a suitable scale is fastened to the spring, it becomes a useful device for measuring force. Often this is called a 'spring balance', although a 'spring scale' would be a better term. Spring balances are more compact than pan balances, and easier to use. However, it is easier to make a pan balances accurate. Nevertheless, spring balances are commonly used in many familiar situations. Here are some activities which can help children become more familiar with the spring balance as a means of measuring weight or any other force.

Demonstration

How is a spring balance used?

Materials required
spring balance
assorted small weights

Show a spring balance to the class; and explain its various parts. It has a hook, an indicator, a scale and a ring, as in Fig. 4-18. The indicator shows on

the scale how much the spring is pulled. Put on 50 grammes of weight. Observe how much the indicator has moved. Now put on 100 grammes of weight and note the distance through which the indicator has moved. The latter distance is twice the former.

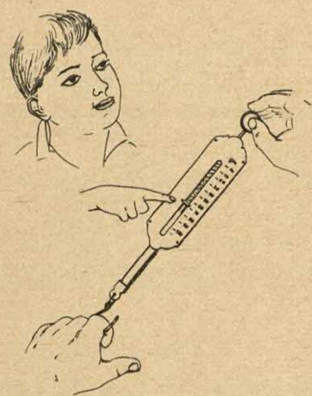


Fig. 4-18
A spring balance is very useful for measuring force.

Prepare a spring balance from a rubber band. (Show the students how a rubber band stretches more and more, when more force is applied at one end.) See Fig. 4-19.

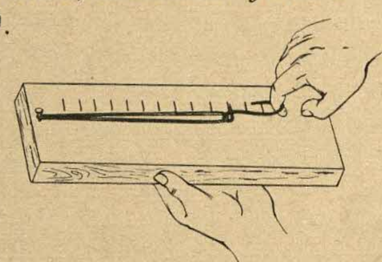


Fig. 4-19
This simple 'rubber band' balance is easy to make and easy to use.

2. MOVING OBJECTS ENCOUNTER THE FORCE OF FRICTION

Children have in previous classes considered many sources of force—including weight, muscles, stretched springs, and the buoyant force supplied by fluids. Of course, there are many other sources of force, including those which are electrical or magnetic in nature. But one of the most common sources of force is friction. Friction supplies a force only in opposition to some force or motion. A large block of wood placed undisturbed on the ground involves no friction. But if a workman pushes on it as though to move it, there is friction-force to oppose the applied force. If the workman's applied force is slight, the force of friction prevents all movement. If the workman pushes hard enough, he moves the wood. Even so he encounters the force of friction, which still opposes the intended motion.

This major concept about friction is interesting and important. Much of the evidence which children can apply to the occurrence of friction are matters of everyday experience. The task of the teacher, then, is to draw on these familiar experiences, and supplement them with controlled experiences

in the classroom. On the basis of these, he can help students arrive through their own thinking at most of the important sub-concepts which follow.

2(a). A FORCE IS REQUIRED TO MAKE AN OBJECT SLIDE ALONG A SURFACE

A book or any object lying on a table will not move by itself. Some force is required to make it move along the surface of the table. To move furniture, one must push the pieces from place to place. Whenever a piece is moved, the force of friction between the floor and the thing moved is overcome. Here are some activities to show children that force is required to make an object slide along a surface.

Investigation

Can a thing be set in motion without force?

Materials required
brick or book or
other such object
string
spring balance

Tie a string around a heavy object such as a brick or a book. Attach a spring balance to the string and pull the object slowly along the surface of the table, as in Fig. 4-20. The indicator of the spring balance will show the force required to make the object slide. Repeat the experiment with larger or smaller objects.

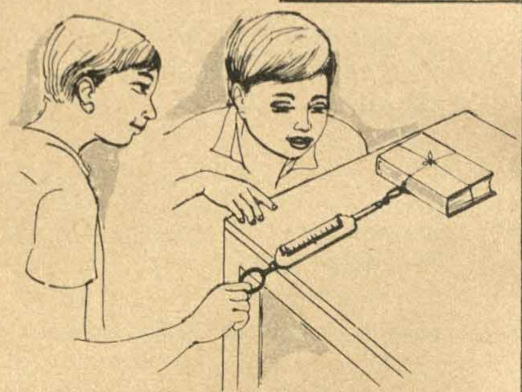


Fig. 4-20
Some force is required to make a stationary object start moving.

Investigation

How does an object behave if there is practically no friction?

Materials required
smooth round ball
smooth table top

Many people have the idea that if there were no friction at all, no force would be required to put an object in motion. This is not true. Friction cannot be completely eliminated in the classroom. Even so, this activity can help children to come to the proper conclusion. Place a perfectly round, smooth ball on a very flat, smooth table top. If the table top is tilted ever so slightly, the ball rolls down the incline. However, it is possible to adjust the position of the table top so that the ball will not roll at all.

When so adjusted, it may be possible to make the ball move with a blade of grass, or by simply blowing on it as in Fig. 4-21. However, *some* force is needed to set the ball in motion. This is a particularly impressive investigation if done with a steel ball bearing on a piece of plate glass.

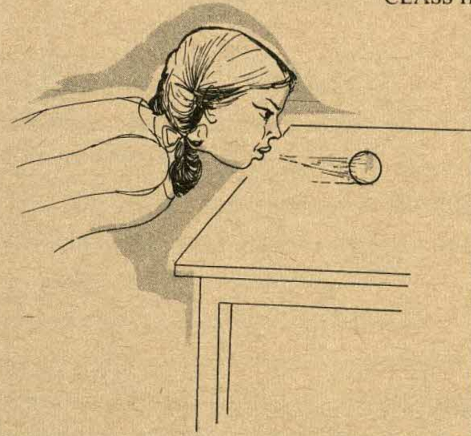


Fig. 4-21
Even though the force may be small, some force is required to set an object in motion.

Attempt to move a very small object across a table top by pulling on it with a slender rubber band. The stretching of the rubber band indicates that some force, even though very small, is required to set the object in motion.

2(b). SMOOTH SURFACES PROVIDE LESS FRICTION THAN ROUGH ONES

It is common experience that more force is needed to pull a thing on a rough surface than on a smooth one. That is, a smooth surface offers less resistance to motion than shoes are smooth. Hence, it may be necessary to walk rather carefully because of the danger of slipping. The difference between the force of friction offered by smooth and rough surfaces can be easily shown by the following simple activities.

Investigation

How does the smoothness of sliding surfaces affect friction?

Materials required
two bricks
string paper
spring balance

Wrap one of two common bricks in paper, so that it has a smooth surface. Attach a spring balance and pull the brick without the paper along the surface of the floor as in Fig. 4-22.

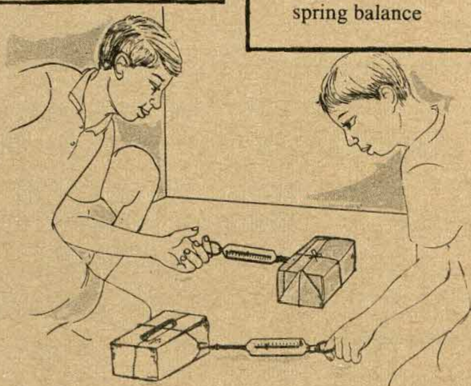


Fig. 4-22
The smoothness of sliding surfaces helps to determine how much friction there is.

Note the position of the indicator. Repeat with the second brick. This time the paper slides along the surface of the floor. Now note the position of the indicator. The rough surface of the bare brick has offered more resistance. Therefore, the force required in the second case is less than in the first case.

Try to slide a book along a stone floor, a table, and a glass surface. Compare the force required in these cases.

2(c). WHEELS REDUCE FRICTION

A hand-cart, a bullock-cart, a motor car, a bicycle—all these vehicles have wheels. Wheels are used to move these vehicles because wheels reduce friction. A carriage without wheels would require a great deal of force to move it along a road. The wheels do not *slide* along the road—they *roll*. Rolling friction is usually much less than sliding friction. Wheels, therefore, reduce friction a great deal. The following experiments will help student understand this clearly.

Investigation | **How do wheels affect friction?**

Materials required
toy wagon or other small toy with wheels

Obtain a toy wagon. Use a spring balance and drag it along the surface of the table as in Fig. 4-23. Observe the reading of the balance. Repeat with the wagon up-side-down so the wheels are not used. Again observe the reading. This reading is much larger than the former one.

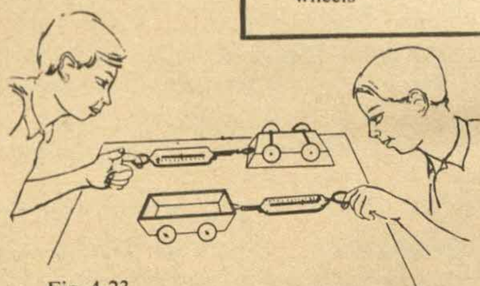


Fig. 4-23
Rolling friction is less than sliding friction.

Compare the force needed to roll an unopened tin can along a table with the force needed to slide it on its flat end.

Remind children how workmen roll *barrels of tar or oil rather than* sliding *them on their flat ends.*

2(d). LUBRICATION REDUCES FRICTION

It is very common to put grease between the wheel and axle of a bullock-cart or a bicycle. This reduces the friction between the wheel and axle and the movement becomes smoother and easier. This method of using grease or oil to reduce friction is called *lubrication*. Machines need frequent lubrication to run smoothly. Without lubrication, the motion of the machine will be resisted by the force of friction. The effect of lubrication on friction can be shown to the students in the following ways.

Investigation

How does lubrication affect friction?

Materials required
wood slab big enough to sit on
grease

Allow a child to kneel or sit on a slab of wood, which rests on a smooth floor of wood or concrete. Challenge another child to move him by pushing on the edge of the wood slab, as in Fig. 4-24. Now provide lubrication by putting grease between the bottom of the slab and the floor. Is there any difference in the force required to slide the slab and its load across the floor now that the surfaces are lubricated?

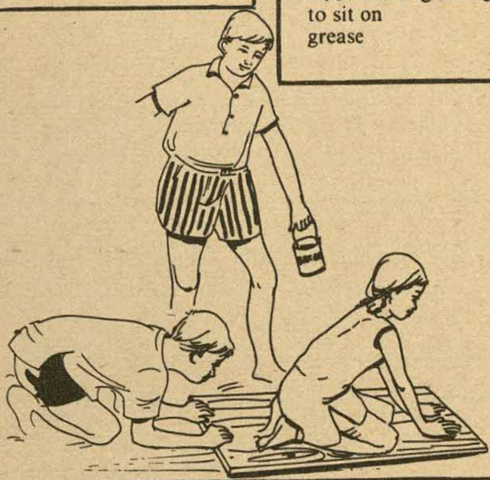


Fig. 4-24
Friction can be reduced through lubrication

Let the students have a tug-of-war with dry hands first and then with their hands greased or covered with soap.

Let a student hold a glass in his hand tightly while someone else tries to twist it. Then apply oil to his hand and try again. Ask the student to describe the difference.

2(e). FRICTION IS SOMETIMES DESIRABLE

It is very common experience for people to try to reduce friction. They provide smooth sliding surfaces and they lubricate them often. They provide wheels or rollers to reduce friction to a minimum. So common are these efforts that people often get the idea that friction is undesirable. This is certainly not the case. Here are some activities which can help children understand that there are many situations where friction is highly desirable.

Investigation

Is friction necessary for walking and running?

Materials required
grease or soap

Permit a child to try to walk or run on a surface made slippery by grease or soap, or even by mud. When there is very little friction between the feet and the ground or floor, is walking or running more difficult? What measures do people sometimes take to *increase* friction between their feet and the floor or the ground?

Discuss with children why it is dangerous for automobiles and trucks to move when the roads are wet and muddy.

Let a child try to stop his bicycle on a wet or muddy spot in the road. Would increased friction help him control his cycle?

3. PEOPLE OFTEN NEED TO EXERT A FORCE THROUGH A DISTANCE

Sometimes when a person wishes to lift an object, he merely wants to support it against the pull of gravity. That is, he wishes to apply an upward force equal and opposite to the downward force of weight. As a result the object will be supported, but it will be motionless. More commonly, however, a weight is lifted in order to *raise* it. A workman lifts a piece of steel from the floor *up* to his work bench, a person climbs *up* a ladder, a lift in a tall building brings its load of passangers to a *higher* position. In these cases, *a force is exerted through a distance*. Scientists say that when a force is exerted through a distance, *work* has been done.

In this major concept children will have an introduction to this scientific concept of work. It is a very common idea, and an extermely important one. It underlies much of man's understanding of tools, machinery.

and engines. In the broader sense, the concept of work provides an introduction to the understanding of energy—one of the most fundamental ideas in all of science.

3(a). WHEN OBJECTS ARE SUPPORTED—JUST KEPT FROM FALLING—A FORCE IS EXERTED, BUT NOT THROUGH A DISTANCE

It is very common to support objects against the force of gravity. When things are just supported, they do not move. A table supported by the floor, a book supported by a table, an umbrella supported by a peg are examples of stationary things. They are just supported against the force of gravity, but they are not moved.

An object hung by a string is also supported against gravity. It will also not move unless somebody swings it. Similarly an object supported by water will not move unless there is something that disturbs it. The same is true of a bridge supporting a truck, or a woman supporting a jar of water on her head. In all these cases a force is exerted, but there is no movement through a distance. This idea will be clearer to students if their attention is drawn to some of the things around them in the following ways.

Discussion

Do we often support things without moving them?

Invite the attention of the students to some stationary things around them. Emphasize that these objects do not move. Whatever supports these stationary things is acting against the force of gravity. These two opposing forces are balanced. Neither force is exerted *through a distance.* The teacher can further illustrate this by placing a book rather carelessly on the edge of the table so that it falls down, and then remarking: 'The book fell down because it was not properly supported.'

Note that the walls of a building exert an upward force to support the roof, but there is no movement involved. This is also true of a person supporting his own weight with his legs when he merely stands still. Help the children to find other common examples of force without motion.

3(b). WHEN AN OBJECT IS LIFTED TO A HIGHER PLACE, FORCE IS EXERTED THROUGH A DISTANCE

What happens when a girl pulls a bucket of water out of a well? She hauls the water from deep underground right up to the level of her hands. Here, the force she applies *moves* the bucket through a distance. The

force is exerted through a distance. When a porter carries luggage up a staircase he is exerting a force through a distance. When a worker is loading his cart with bricks, he is lifting the bricks through a certain height. Hence, the force he is applying is force exerted through a distance. This can be made clearer to the students through guided activities such as the following.

Demonstration

Under what common conditions is force exerted through a distance?

Materials required
assorted common objects
string
spring balance (if possible)

Support a book or a rock with a string and a spring balance. This is the equivalent of weighing the object. Now lift it slowly and gently from the floor to the table top as in Fig. 4-25. Note that the force involved is the same (for this the object must be raised very slowly and steadily). Now, however, instead of the force *merely supporting* the object, it is *raising* it. The force is being exerted *through a distance*.

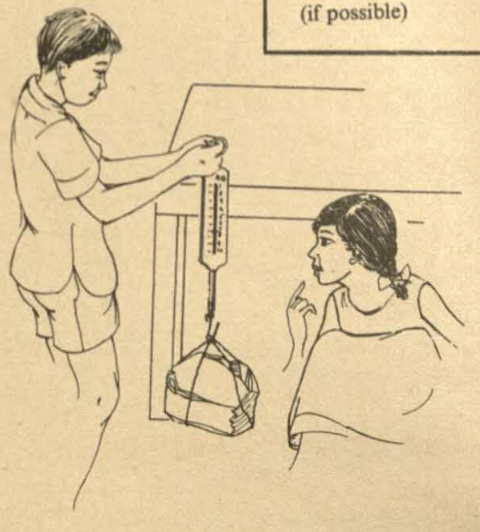


Fig. 4-25
When an object is lifted, the force is exerted through a distance.

Discuss with children other examples of force being exerted through a distance when objects are lifted. Encourage children to think of such examples as bricks being carried up a ladder, a squirrel climbing a tree, and a helicopter or a rocket in vertical ascent.

3(c). WHEN A LOAD IS HAULED ALONG A ROAD, FORCE IS EXERTED THROUGH A DISTANCE

Students have now seen that force is exerted through a distance when some object is raised. In such cases the force applied is equal to the weight being lifted. In a some-

what similar manner, a force is exerted through a distance when a box of stones is dragged along the ground. Here, however, it is not the *weight* of the object which must be overcome by the applied force. Rather it is the *friction* offered by the movement of the bottom of the box along the surface of the road. This is still an example of a force being exerted through a distance. However, the force does not overcome the *weight* of the object, and the force and the motion are not upwards, but are in a horizontal direction. This is a somewhat difficult concept, but a most important one. Here are some activities which can help children grasp the idea.

Investigation

Does a sliding motion involve force exerted through a distance?

Materials required
book or stone
string
spring balance
(if possible)

Use a string to fasten a spring balance to a book or a brick or a stone. Slowly and steadily drag the object across the table top or across the floor as in Fig. 4-26. Have children note on the spring balance the force which is causing the motion. Is this force horizontal or vertical? Also let them say whether or not the motion is in the same direction as the applied force. Is this a case of a force being exerted through a distance?

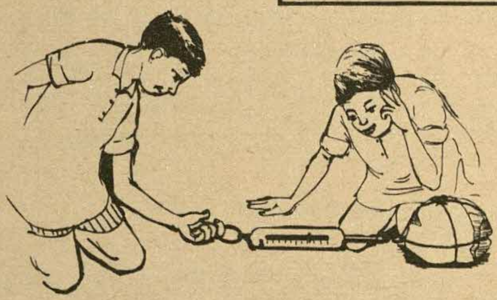


Fig. 4-26
In this activity, the direction of the force is the same as the direction of the motion.

Investigation

What force is involved in the work of hauling loads along horizontal surfaces?

Materials required
toy-cart
heavy objects to put in toy-cart
spring balance
string

Load a toy-cart with some heavy objects and pull it along a smooth table top with a spring balance, as in Fig. 4-27. Observe and record the force required to move the toy-cart slowly but steadily. Now use the spring balance to weigh the toy-cart and its load. Note that the weight (force) of the material is much greater than the force necessary to move the toy-cart. Discuss with the class which of these two forces is involved in the work being done. Remind them that work is force multiplied by distance, but

that the force and the movement *must be in the same direction*. In this case, therefore, the work involves the force measured horizontally—in the direction of the movement. Indeed, the weight of the toy-cart and its load is not directly involved in the work done.

Fig. 4-27
The work involved in moving the toy-cart equals the distance moved multiplied by the force required to move the cart (not by the weight of the object)

Help children analyse the direction of the force and the direction of the movement when a bullock hauls a cart, when a locomotive pulls a train of cars, or when a boat is paddled through the water.

For Better Understanding

There is a key point in this sub-concept about which teachers and students must be abundantly clear. This key point is at the root of the phrase *a force applied through a distance*. In analysing such situations, one must be very sure that the right force and the right distance are considered. For example, a workman slides a 100 kilogram steel bar across the table a distance of two metres. It requires 15 kilograms of force for him to slide it. Here the force to slide the bar does not overcome the weight-force of the bar (100 kgf) but the frictional force opposing motion (15 kgf). So this is a case of a force of 15 kgf being exerted through a distance of two metres. It makes no difference how high the table is, nor how tall the man is, nor how much he weighs! In analysing such situations, it is necessary that one be very careful to find the force which is acting through the distance involved in the movement.

Children often ask pointed questions in this part of their science course. For example, they are told that in the scientific sense of the word, no work is done when an object is carried unless it is raised higher. Yet they all know that the porter gets very tired when hauling loads, even though the parcels are no higher at the end of the haul than they were at the beginning. If the work is zero, why is the workman so tired? A thorough analysis of this situation shows why it is so. The work that the workman does is only in overcoming friction involved. If he hauls the parcels in a cart, there is some friction involved. If he carries them, there is still internal friction of moving muscles. But the real source of his tiring is that his muscles are exerted *only to lift* the heavy objects. This is a good example of a

non-scientific interpretation of the word 'work'. (See also sub-concept 3(d) which follows). The porter is genuinely tired—his muscles have truly exerted themselves. But being 'tired' is not the same as having performed work in the scientific sense.

This is a difficult concept for students and for adults as well. Teachers should not expect that class III students will understand all the details. However, it is worthwhile—and it can be effective—to make a beginning towards having students understand this important aspect of work involved in physical movement.

3(d). WHEN A FORCE IS EXERTED THROUGH A DISTANCE, SCIENTISTS SAY THAT WORK HAS BEEN DONE

People do many things called work. A day of busy writing makes a man tired and he says, 'I have done a lot of work'. People often say they are 'at work' when they are earning a living. Children sometimes say they are 'working' when they are carrying out some required task rather than playing. But a scientist would not say that any work has been involved in these situations. Scientists look upon work in a different way.

The scientific definition is that work is done only when a *force is exerted through a distance*. When a girl picks up a book from the floor and raises it to the level of the table, she has done work. When a boy is simply climbing a ladder, he is doing work, because he is exerting force against gravity (lifting his weight) and exerting that force through a distance (climbing higher). Teachers can build upon some activities which students can do and thus help them identify the concept of work implied in some of them, like this.

Investigation	**How does lifting an object involve work?**	*Materials required* *stone or book*

Ask a child to pick up a stone lying on the floor and place it on the table. He has exerted force which *moved* the stone through a distance to the top of the table. He has, therefore, done work.

Take each activity named by the students and find out whether they have understood the relationship of work with force and distance.

Discuss with students common situations where work is being done. Thus, when a lift raises a load, it exerts a force through the distance lifted. A workman sliding a steel bar across the table exerts a horizontal force to overcome the opposing horizontal force of friction.

Describe common situations where no work is being done. Thus, a table exerts an upward force on a steel bar to keep it from falling. However, the force produces no motion—the force is not acting through a distance. Hence no work is being done.

3(e). ENERGY IS REQUIRED TO DO WORK

Work cannot be done 'for nothing'. A lift does not raise its load of passengers without some motor or some animal to operate it. A workman cannot exert force through a distance indefinitely—from time to time he needs rest and food. An automobile engine needs petrol to continue its operation. Thus, 'something' is required in order for work to be done. Scientists have given this 'something' a special name. This term is 'energy'. Thus, scientists say that *energy is required to do work*. This energy may come from man or another animal, who in turn gets energy from food. Energy for water power comes from the moving water in the river. Automobiles and aeroplanes get their energy from petrol or jet fuel. There are many sources of energy. Some source must be available for work to be done. Scientists often say, 'Energy is required to do work'. They also say, 'Energy is the ability to do work'. Sometimes they say, 'Work is one form of energy'.

At this class level, only the beginnings of the energy concept are given to children. But they are sound beginnings for one of the most important understandings in all the realm of science. Teachers can help students comprehend the energy concept through discussions and activities which use the concept simply but accurately in very familiar situations. Here are some examples of such learning activities.

Demonstration

Can we actually feel that our bodies need energy to do work?

Let a boy climb up on a stool many times—perhaps as many as thirty times. By this time he will be somewhat tired. Ask him how he feels. Help him describe his feeling in such terms as 'I can't do it any more until I rest' or 'This makes me hungry'. Help the class realize that this is familiar evidence that energy was required to do the work of getting up on the stool so many times. Ask children to describe times when they have felt very tired—in need of food and rest—because of work they have done.

Investigation

Where does steam get the energy to do work?

Materials required
Iron pipe closed at one end
source of heat
cork

Put a little water in an iron pipe which is closed at one end and close it tightly with a cork. Heat the pipe on a spirit lamp as in Fig. 4-28. The cork soon blows out of the pipe. What has blown the cork out? It was the steam inside the pipe which exerted force on it. This force has moved the cork through a distance. The steam has done work. Heat changed water into steam; steam did work on the cork. In this case, heat is the source of energy.

Fig. 4-28
Steam gets its energy from a source of heat

Discuss with children various common examples of work being done. In each case, help them recognize the source of energy which makes the work possible.

Discussion

Where do supporting devices get their energy from?

Challenge students to identify the source of energy for holding a heavy rock on a wooden frame. Actually the force applied to hold the rock merely *supports* it—the force does not lift it through a distance. Hence no work is done. Therefore, no source of energy is required. Remind students that the wooden stand could support the rock for years and years without any source of energy—no work is involved.

For Better Understanding

The sources of energy for performing work are of many kinds. Sometimes the energy comes from muscles, or from steam, or from electricity. But where do these energy producers get more energy for continued operation? The bullock gets energy

from the food he eats, mostly grass. The grass gets its energy from the sun. A steam engine gets energy from steam; steam gets its energy from coal. The coal is formed from plants which lived hundreds of millions of years ago; they got their energy from the sun. Water power gets its energy from moving water. The water moves because it was lifted from ground or ocean level to the mountain heights in the process of evaporation. In each of these three examples, the sun has been the prime source of energy. This is the case in almost every example of an energy source which can be named!

4. PEOPLE USE MANY SIMPLE MACHINES TO HELP DO WORK

Many times every day people have a need to perform work. That is, they have a need to *exert a force through a distance*. It may be pushing themselves along on a bicycle overcoming the force of friction. Or they may be lifting shovels full of dirt against the force of gravity, pounding nails into wood, changing tyres, opening cans, or even cutting paper. These and countless other common tasks are examples of using muscular force to do work—exerting a force through a distance.

Sometimes these tasks are simple or pleasant. The forces and distances involved may be so small that it is easy and convenient to do these simply with the aid of muscles. But sometimes the tasks require a large force. This would be the case when one is chopping down a tree, or jacking up an automobile, or lifting a heavy load up to the first floor of a building. Most human beings have difficulty in lifting load of more than about 100 kilograms. Often the doing of tasks involving even smaller force are impossible—or unsafe—or unpleasant. In cases like these, man has learned to use simple machines to help him in his tasks.

Although all children at this class level have used many kinds of simple machines many times, they have never before had a chance to analyse just what the machines do and how they do it. Often they confuse *machines* with *engines*. They fail to realize that engines operate on some kind of fuel, while simple machines are simply mechanical aids to the muscles.

Children at this class level already have most of the concepts necessary to understand the elements of simple machines. They know about force, about distance, and about work. And they have had wide experiences with simple machines in their daily living. However, children at class III level will have only an introduction to this important subject. It is designed to be a simple introduction, but one which is fundamentally correct. This beginning will serve as an application of their knowledge of force, distance, and work. It will also lay a useful foundation for a more mature study of machines in future classes.

4(a). A LEVER CAN BE USED TO EXERT A LARGE FORCE THROUGH A DISTANCE

It is difficult to lift a heavy stone even a very little distance above the ground; simply by hand. A lever bar can be used to lift the stone. A tightly fitting lid of a tin cannot be lifted out by hand. A spoon working as a lever will lift it easily. Heavy logs of wood are taken from one place to another with the help of levers. Activities like these can help students see how levers are used.

Investigation

How can a lever be used to help lift a heavy stone?

Materials required
crow bar or
long strong stick
heavy stone

Set a large stone on the ground. Ask one of the students to lift it. Then let two students try to lift the stone. It is too heavy! Now help a small child to use a stick as a lever as in Fig. 4-29. He lifts the stone easily.

Fig. 4-29
A lever can be used to help in lifting heavy objects.

Demonstration

Are there some common tools which are really levers?

Materials required
claw-hammer
pliers
screw driver
wood
nail

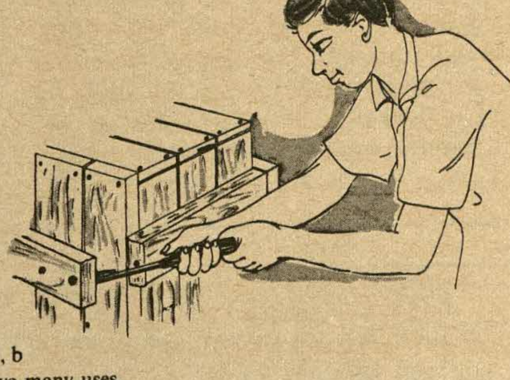


Fig. 4-30a, b
Levers have many uses.

Drive a nail into a piece of wood and challenge students to pull it out with their bare hands. Then show them how it can be done using a claw-hammer as a lever. Similarly, show how pliers can be used to exert enough force to crush wood, or to bend a nail. A screw driver can be used as a lever to pry apart two boards which have been nailed together. Challenge students to name other common tools and household devices which are levers. See Fig. 4-30.

4(b). A HILL OR A RAMP HELPS ONE LIFT A HEAVY LOAD TO A HIGHER PLACE

A heavy load may be shoved up a tilted plank from the ground and put in a truck. A tall building has a stair-case. People use the stair-case to carry themselves up to a higher floor. Long ramps are constructed to carry building material up while a building is under construction. A winding road helps a car to climb up a hill. The following activities illustrate how a simple inclined plane can be used to help lift heavy loads.

Investigation

How does an inclined plane help us lift heavy loads?

Materials required
4-wheeled cart
board to serve as inclined plane

Put enough stones in a small four-wheeled cart to make it difficult but possible for a boy to lift. Ask one of the students to lift it from the floor to a low table. Then get a plank of wood wide enough to support the cart. Arrange it as a ramp from the floor to the table. Ask the same boy now to pull the same loaded cart upward along the plank. The boy can easily move the cart along the plank and thus raise it to the level of the table. The plank has helped the boy to lift a heavy load. Encourage children to identify other examples of inclined planes which are common to their experience. Among them are stairways, shoe irons (shoehorn) and even a simple pathway up a hill. See Fig. 4-31.

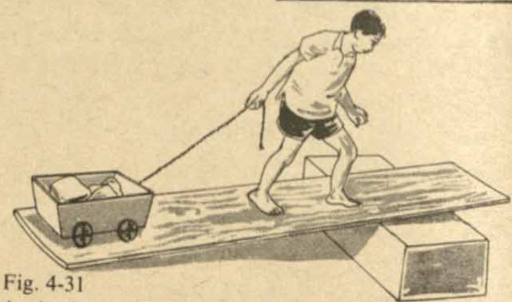


Fig. 4-31
An inclined plane can be used to help in lifting heavy objects.

Help children to recognize the principle of an inclined plane in such devices as a wedge, a chisel, a knife, and a screw. (A screw can be thought of as an inclined plane wrapped around a rod.)

4(c). LEVERS AND INCLINED PLANES DO NOT DO WORK THEMSELVES; THEY HELP PEOPLE DO WORK; THEY ARE EXAMPLES OF SIMPLE MACHINES

A long lever used to lift a heavy stone or a plank used to lift a heavy weight are examples of simple machines. A prying bar is a machine. It is an example of a lever. The wooden plank or a staircase is also a simple machine, an example of an inclined plane.

Levers and inclined planes do not do any work by themselves. These simple machines help man to do work. This important point can be made clear through activities such as these.

Investigation	**Are simple machines capable of doing work?**	*Materials required* strong stick heavy stone

Bring a heavy stone and prying bar to the classroom. Place the bar in position as a lever. Convince the students that the bar by itself is unable to lift the stone. Ask one of the students to push the high end of the bar down as in Fig. 4-29, and ask others to observe. The stone is lifted. Now see if the lever can do this task by itself as in Fig. 4-32. Help the students understand that simple machines do not do any work by themselves but they can be of help when people have heavy tasks to do. The same kind of demonstration could be given with a pair of pliers used to crack a nut. By themselves, the pliers can do nothing. The user must apply the proper force to the pliers.

Fig. 4-32
This simple machine can do no work by itself; some energy must be put in to the lever before it will operate.

Challenge children to name any simple machines which can do work without someone exerting a force on them. (Students may name engines, where the energy comes from a fuel.) Simple machines cannot do work by themselves; a force must be supplied.

Use a plank to carry a stone up a table; convince the students that the plank does not carry the stone up. The boy carries the stone along the plank. The plank has helped the boy do the job.

Help children analyse a few common simple machines to see where work is involved. With help, they can see the jaws of the pliers do work as they exert a force through a distance (as they crack the nut), and that the user exerts a force through a distance as he squeezes the grips of the pliers toward each other. The user does work on the simple machine, and the machine transfers this work to the nut to be cracked. The primary source of energy is not the simple machine, but the person who uses it.

5. PEOPLE OFTEN NEED TO MEASURE AREA

Suppose you want answers to common questions like these:

How many children or adults can be comfortably seated in a room?

How much time is required to whitewash a wall?

How much paint is required to paint a box or a building?

These questions are concerned with the measurement of *surface* or *area* of objects. Children's experience has made them *aware* of the concept of area, although they may not realize it. In this major concept the teacher can start with what students already know, and help them build it into a simple but useful understanding. The four sub-concepts which follow are steps in that growth of understanding.

5(a). AREA IS A MEASURE OF THE AMOUNT OF SURFACE

Students have heard such expressions as the number of acres of land in a farmer's field, the quantity of cloth required for a frock, or the number of square metres in a living room or in a house. Teachers should help them realize that this is the concept of area. Here are some activities which can help make this clear to children.

Discussion

Can we learn to use the term 'area' properly?

Ask a pupil how many children can be seated in the classroom. Ask how many adults can be seated in the same room. Let students tell why the number of adults is less. Now suggest a bigger or a smaller room and ask a pupil to

tell the number of children or adults that can be seated there. Help students understand why a large room can contain more persons. In these discussions make frequent and accurate use of the term 'area'

Ask which table requires more cloth to cover. The one which is 1 *metre by* 2.0 *metres or the one which is* ½ *metre by* 2 *metres.*

Hold up a square piece of cloth or paper and ask children to describe how big it is. Repeat with two pieces of different size and ask them which is larger. Can they prove it?

Discuss with children which wall requires more painting material, the one which is 6 *metres by* 5 *metres or the one which is* 10 *metres by* 4 *metres?*

5(b). AREAS CAN BE COMPARED WITH EACH OTHER

By now children know that 'area' and 'amount of surface' mean the same thing. They have also had experiences at home and at school where they compare two or more areas to see which is largest, which is smallest. In this sub-concept children learn more about area comparisons, and learn to make them more systematically and more accurately. They will also be led to the idea that a given area can be measured by comparing it with an accepted standard of area. Here are some activities which can help them increase their understanding in this sub-concept.

Demonstration | **How much bigger is one area than another?** | *Materials required* paper

Prepare two squares of paper, one 10 cm on a side, the other 20 cm on a side. Ask children to compare them in size. All will know immediately which is the larger. Now ask them how much larger one is than the other. Many will say it is twice as large, because it has a side which is twice as long. Now get three more squares, each 10 cm on a side. Show the class that four of the smaller squares just cover the larger square, as in Fig. 4-33. In terms

of area or amount of surface, then, the larger square is four times as big as the smaller one. Help students realize that they are comparing areas directly. Help them understand what it means to say that the large square has an area of four small squares.

Fig. 4-33
It is often easy to make a good comparison of areas.

Investigation

How can we describe a given surface in terms of some smaller unit of area?

Materials required
paper

Prepare many squares of paper each 10 cm on a side. Show children how these can be used to cover a given table top, a certain section of the floor, or a scarf or kerchief spread out flat, as in Fig. 4-34. Identify the 10 cm squares as 'standard units', or give them an artificial name, like the name of the village, or of the teacher, or simply 'unit area'. Help students learn to describe table tops and scarfs and such things as having an area of 'about 12 of our units', or 'nearly six units of area'. Help them realize that they are not only comparing areas, they are literally measuring them through this comparison. Do not be too concerned about the accuracy of the comparison; it is far more important just to get the idea of comparison-measurement of areas.

Fig. 4-34
We can measure the area of a scarf in terms of smaller squares.

Discuss with children such questions as 'How many sheets of newspaper would be required to cover one window of the classroom?'

and 'How many postage stamps would be needed to cover completely a small envelope?'

5(c). THE SQUARE METRE IS THE ACCEPTED UNIT OF AREA

Children are already familiar with the idea of standards of measurement and why they are necessary. They also know that all measurement standards in India are based on the metric system. They understand that the kilogram provides the accepted standard of weight, and that time is measured in familiar units such as seconds, and hours, days and years. They know that the metre is the legal standard for length. Accordingly, it is a logical step for them now to understand that the accepted standard for area is the square metre. Here are some activities which can help students make this extension in their understanding of standards of measurement.

Discussion

How can we select a useful standard unit of area?

Materials required
paper

Refer to the activities accompanying Fig. 4-34. Ask children what was 'special' about the square used there as a unit of area. Ask why it could not have been smaller or larger, or rectangular or triangular or round? Have some of these other shapes already cut out of paper and see how children would like to use them for measuring the area of the schoolroom floor. Since the students are already familiar with the metric system, ask them if there is any shape related to the metre that might be used as a standard unit of area. Help them realize that a square shape is easier to understand and to use. Show that a square metre would fit in nicely with the metric system of measurements, the standard of our nation and of the scientific world.

Investigation

How can we use a simple square metre to measure the area of the floor?

Materials required
metre scale or measuring tape
paper

Prepare a few squares of paper one metre on a side. Help students to use this to measure the area of a small room. They start in one corner, then move the squares about until they have successively covered all parts of the room as in Fig. 4-35. The number of times they lay a square down is the approximate area of the room in square metres. If the class is familiar with the

computation of the area of a rectangle, have students measure the length and breadth of the room and compute the area. How does this compare with the area as determined by the previous method?

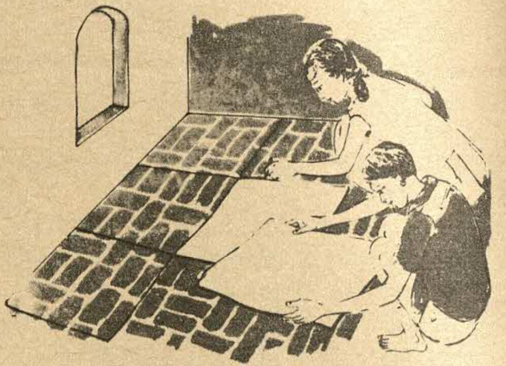


Fig. 4-35
The area of a floor can be measured by using paper squares one metre on a side.

Discussion

How can we know the area of a tiled floor?

Recall to the mind of the children the floors of houses or buildings laid with square slabs of marble or other stone. You may take the children to such a room. Suggest the surface of one slab as the unit of area. What does the area of all the blocks indicate? Ask students how they can find the area of the room. What does the number of slabs indicate, if each slab is a unit of area?

Discussion

How can we know the area of a latticed window?

Show the children a latticed window Ask them to count the number of holes in the lattice. What does the total of all the holes measure? Suggest that they consider one hole as the unit. Ask how they can express the area of the window.

Discuss with children other useful metric standards for area. For small areas, square centimetres or square millimetres are used. For larger areas there is the 'are'—(100 *square metres) and the* hectare *(*10,000 *square metres).*

5(d). THE AREA OF SIMPLE SHAPES IS EASY TO CALCULATE

Adults seem to find it almost 'second nature' to calculate the area of simple shapes like squares and rectangles, triangles and circles. Unfortunately, most adults have learned this simply by memorization. Often adults do not know why their calculations are done the way they are. There are ways, however, in which children can be led to find out for themselves how to compute the area of squares and rectangles. Here are some suggestions for how teachers can help students do this.

Investigation

How can the area of a rectangle be computed?

Materials required
paper
measuring scale

Have a rectangle of paper 30 cm × 50 cm prepared, and also at least 15 squares of paper, 10 cm on a side. Help children use the now-familiar technique of moving one square about (in 15 moves) to cover the area of the rectangle. Point out that by actual comparison of the 'standard square' with the unknown rectangle, they have found that the rectangle contains 15 of the reference squares. Now produce the larger supply of 10 cm squares and invite students to place all 15 of them on the rectangle at once as in Fig. 4-36. Help them realize that there are three rows of five squares each (or five rows of three squares each), and that this is 15 squares, by simple multiplication. Experiment with other simple rectangles. Try to arrange the discussion so that the students themselves arrive at the notion that the area of a rectangle can be computed by multiplying its length times its width.

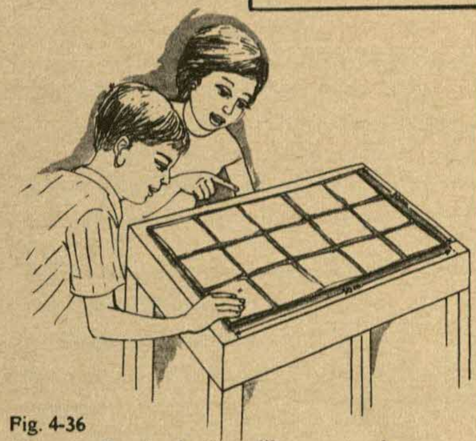


Fig. 4-36
The area of a simple shape like a rectangle can be computed by multiplying its length times its width

Investigation

How can we compare areas whose shape is different?

Materials required
paper
ruler

Pose a problem such as this: 'Of two rectangular papers, one 40 cm by 30 cm and another 60 cm by 20 cm, which is larger and how do you know?' Students may suggest a solution by laying one on top of the other, as in Fig.

4-37. This will not be convincing enough unless one of the papers is cut. Now mark each paper along its length and breadth into 10 cm sections. Draw the vertical and horizontal lines joining each pair of opposite points. Ask them to count the number of 10 cm squares on each paper. Help students see that the areas of both are the same. Ask what each small square on the paper stands for; help students express the area as 100 square cm. Ask whether the area can be found out directly by knowing only the length and breadth of the cardboard. (Suggest if necessary that 40 cm × 30 cm and 60 cm × 20 cm can give the area here). (Individual children can easily do this with rectangles 3 cm × 4 cm and 6 cm × 2 cm, and with small squares one centimetre on a side.)

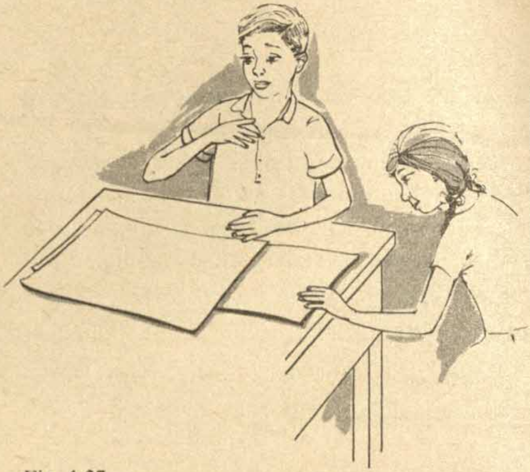


Fig. 4-37
Sometimes the shape of two areas makes it difficult to make a direct comparison.

Discuss with students the notion that a square is simply a special case of a rectangle. The same method of computation can, therefore, be used for a square as for a rectangle.

For Better Understanding

The development above is an example of concept formation based on observation, experimentation—and some intuition—rather than on mere momorization of formulas. If students can be helped to see and to use the logic of mathematics, they will understand it better and will also enjoy their use of mathematics more. In addition, they will remember what they have developed in their own minds better than that which they have acquired simply by rote memorization.

Teachers will do well to integrate these science learnings about measurements with appropriate subjects in mathematics. At this class level, however, teachers should resist the temptation to go too far and too quickly. It would be of little value at this stage to go into the area of triangles, and most unwise to approach the areas of circles.

6. PEOPLE OFTEN NEED TO MEASURE TEMPERATURE

Long before they come into class III, children are aware of the concept of temperature. They speak freely and understandingly of hot and cold water, of warm and cool

weather, of summer days when they feel too warm, or of a cold wind in winter. Over ordinary ranges of temperature, children can easily tell which of two jars of water is warmer, or which of two pieces of iron is cooler. They can correctly predict that ice will feel cold to their hands, and that boiling water is dangerously hot. Yet in general, these children know little of the actual *measurement* of temperature. Except for phrases such as 'too cold' or 'very hot'. or 'a little cooler', they do not know how to describe temperatures with which, in fact, they may be perfectly familiar.

In this major concept children's attention will be focused on matters of temperature. They will see that their senses of heat and cold have serious limitations. They will explore the simple and common ways of measuring temperature and the scale on which temperature is expressed.

6(a). TEMPERATURE CAN BE THOUGHT OF AS 'HOW HOT' OR 'HOW COLD'

Temperature is a concept which is already familiar to children at this class level. The purpose of this sub-concept is to help children translate their experiences with 'hot' and 'cold' into the more mature notion of a complete range of temperatures, with many gradations between the extremes. The learnings here are partly matters of simple vocabulary, and partly matters of recognizing intermediate values of temperature between the simple extremes of 'hot' and 'cold'. Here are some activities which can help children thus increase their understanding.

Discussion

How can we describe an object which is neither hot nor cold?

Materials required
jar of hot water
jar of cold water
empty jar

Show the class two similar jars each containing clear water. One of these is hot, the other is cold, but the children do not know this. Let some children feel these and describe their hotness or their coldness. Now pour equal quantities of hot and cold water into a third jar. Allow students to feel this mixture. They can be encouraged to describe it as 'neither hot nor cold' or 'luke warm', or in other similar common phrases. Now mix a small quantity of hot water with a larger quantity of the cold water. Children will now find that this is not cold, but merely cool. A mixture of a little cold water with much more hot water turns out to be not hot, but merely warm. In this way, children have not two descriptions of temperature (hot and cold) but five (hot, warm, ordinary, cool, and cold). Ask children if there are not also other temperature conditions between these five descriptions. Help them realize that there are other things colder than the cold water (ice), and things hotter than the hot water (boiling water or boiling oil or hot coals). Help them realize that there are more different 'hot-or-cold' conditions than there are sets of words to describe them.

Throughout this discussion, make frequent and proper use of the word 'temperature'. Help children realize that as they talk about 'hot-or-cold', they are talking about conditions of temperature.

Encourage children to question their parents about 'how hot it was today', or 'how cold it gets in winter'. Usually they will find that the answers are in terms of degrees on a temperature scale. Use this experience to interest students in learning about a way of describing temperature in that manner.

6(b). TEMPERATURES CAN BE COMPARED

Children already know that they can estimate temperatures and describe them verbally. They also know that they can make personal comparisons between different temperatures. What they do not realize is that their sense of temperature is really quite unreliable. In this sub-concept children will be helped to realize that their senses are relatively poor when it comes to making really good estimates of temperature. Here are some activities which can help them acquire this understanding.

Investigation

How reliable are our senses for describing temperature?

Materials required
jar of hot water
jar of cold water
two jars of water at medium temperature

Start with four jars of water, one hot, one cold, and two of medium temperature. Children do not know of these conditions, but the teacher may think of the four jars as *H, C, M* and *M*. Start by permitting one student to put his hand in the *H* jar and describe his reaction. He can then put the same hand into one of the *M* jars. He will describe this as 'cool'. Another student can put his hand into the *C* jar and describe his feelings. Then he can put the same hand into *the other M* jar.

Fig. 4-38
Our sense of temperature is not very reliable.

He will describe it as warm. Only the teacher knows that the two *M* jars are at the same temperature.

Now permit a third child to put his hand, first into one *M* jar, then into the other. Before he reports his results, remind the class that these two jars have already been described, one as cool, the other as warm. But the third student will now insist that they are the same temperature. Help the students realize that this illustrates the fact that the human senses are not very good at determining temperature.

An interesting variation to this is to have a student put one hand into hot water, and the other hand into cold water for about a minute. Now he can put both hands together into a jar of water at medium temperature as in Fig. 4-38. Amazingly, one hand will feel that the water is warm, while the other hand feels that *the same water* is cool!

Encourage children to describe how they feel on a cool night. Descriptions will include such terms as 'cold', 'freezing', 'chilly', 'ice-cold', 'cool' and others. Help them realize that this illustrates that different people sense a certain temperature condition in different ways, and describe it in different terms.

Remind children how in a given room, one person may feel comfortable, another warm, while a third one feel cool. What a poor indicator of temperature our body is!

6(c). TEMPERATURE CAN BE MEASURED WITH A THERMOMETER

Adults are accustomed to measuring temperature with a thermometer. It is common to see a thermometer hanging on the wall of a market place or a public building. Doctors measure the mouth-temperature of a patient with a thermometer. Some cooks use a thermometer to see how hot the oven is where baking will be done. Scientists make abundant use of thermometers in their laboratories.

Learning activities related to this sub-concept are to be found in Unit 2, 'Air, Water and Weather' (major concept I). Teachers should consult that portion of this Teacher's Handbook to find out about these activities. Often there is no need to do these activities twice—once for each unit. Teachers will do well to make these

activities serve both units. It is a good way to provide integration between two or more of the 'units' of scientific understandings of the syllabus.

6(d). THE FREEZING AND THE BOILING POINT OF WATER PROVIDE ACCEPTED STANDARDS FOR TEMPERATURE MEASUREMENTS

The most useful temperature scale is the one usually called 'centigrade' (although the proper term is 'Celsius'). This is the scale which is official in our country and most other progressive countries, and is universally used in scientific laboratories throughout the world. This scale is based on the freezing point and the boiling point of water. By definition, the Celsius scale is one on which the freezing point of water is 0° and the boiling point of water is 100 There are 100 divisions between these two reference points.

Many useful activities to help students understand this are given elsewhere in this Teacher's Handbook. [See Unit 2, Class IV: 'Air Water and Weather', sub-concept 4(c)] See also the 'Scientists at Work' section concerning the early development of the thermometer which is in the same sub-concept, and 'For better Understanding' which follows it.

UNIT 4

ENERGY AND WORK

CLASS IV

Overview

Within the scope of this unit, children in the first three classes have learned about force and its measurement. They have learned about many sources of force, including gravity (weight is a force). They have learned what forces do and how they can be measured. They have similarly learned the beginnings about distance and its measurement and time and its measurement. In all these dimensions and measurements, children have learned of the need for some generally accepted standard. They know that our nation is committed to the use of the metric system for such standards.

In class III students extended their concept of measurement of distance; length —or distance—is strictly a one dimensional measurement. When this is extended to two dimensions, it is a measure of surface area. Class III students also began to learn about temperature and its measurement.

In these earlier classes students were introduced to the all-important notion of force acting through a distance. They learned that this is work in the scientific sense of the word—and that work is a form of energy. They have also had an introduction to the basic concepts of simple machines as devices which people use to help them do work.

Here in class IV, children will extend measurements involving distance (one dimension) and area (two dimensions) to the three dimensional measurement of volume. They will consider the three-dimensional measurement of volume. Building upon this, they undertake to learn about density, the relation between weight and volume, and about the pressure which exists within liquids. In this way they extend their understanding of force to include pressure and the buoyant force which fluids exert on objects which are within them. They also extend their understanding of simple machines to include more of the common devices than they did in class III.

In this class, students also undertake the study of heat. They learn about various sources of heat and that heat may be thought of as a form of energy. They continue to improve their understanding of the principle of conservation of energy. Finally, they have a chance to learn about one more important concept involving measurement. This is the familiar notion of speed. They learn about this not as a fundamental type of measurement, but as one involving distance and time.

These class IV students, then, are learning concepts in science which are themselves

of intrinsic value. They are at the same time learning some of the fundamental notions about physics. These ideas will make it possible in later classes to make even further progress in understanding this aspect of the world in which they live.

1. PEOPLE OFTEN NEED TO MEASURE VOLUME

A length is a separation between two points. An area is a surface bounded by lines. It has no depth or thickness. What is volume? Give depth or thickness to an area and the result is volume. That is, volume is a space bounded by surfaces on all sides. It has three dimensions: length, breadth, and thickness or height. Each of the three is simply a distance.

Children have already had the experience of extending their measurement-of-distance concept to include two dimensions—the treatment of surface area. Now they will have a chance to extend it one step farther and to become familiar with the concept of three-dimensional measurement—the treatment of volume. Children at this class level already have some ideas about volume, but they are fragmentary and not well organized in students' minds. The sub-concepts below are organized so as to help the teacher build on the ordinary experiences of class IV children and develop their understanding of volume to a meaningful degree.

1(a). VOLUME CAN BE THOUGHT OF IN TERMS OF 'HOW FULL', 'HOW BIG', 'HOW MUCH', ETC.

Children at this class level have often come into informal contact with the measurement of volume. Even if they do not *measure* volume, they are aware of the general concept of 'size', and they are familiar with the simple comparison of volumes. Thus, children speak in such terms as 'a cup of milk', 'a bucket of water', or 'a basket of grain'. Although the terms are familiar to them, they have seldom analysed just what the terms mean. Children of this age level do not often see the relation between measures of liquid volume and those of solid volume. Here are some simple activities which can help children begin to think about volume measurement.

Discussion

What are some common ways of describing how much of a substance there is?

Engage the class in a discussion centred around quantities of common materials. Thus, ask such questions as 'How much flour is used in making a stack of chapatis?' 'How much water do you want to drink?' 'How much water can you hold in your mouth?' 'How big is the hole on the ground?' (Refer to a certain hole.) Answers to such questions can be accepted in almost any form—in terms of 'lots' or 'not very much' or 'mouthful' or 'three basketful'. The purpose of the discussion is to help children realize

they are talking about quantities of material. Sometimes this will be discussed in terms of weight, sometimes in terms of volume. Help children realize the difference between these two ways of discussing 'how much'.

Investigation

Is there a difference between 'how much does it weigh?' and 'how much space does it occupy?'

Materials required
two identical jars or cans
water
sand

Help students fill two indentical cans, one with water, the other with sand. Engage them in a discussion of how much meterial there is in each can. By simply lifting them, children can easily tell that the water weighs less than the sand. So in terms of weight, the quantities of water and of sand are different. Help children to realize that in terms of how much space the two materials occupy, they are identical, since each one completely fills a can. Emphasize the space-occupying property of the materials and use the term 'volume' frequently. In discussing quantity of materials, make frequent use of volume measures, like a cup, a jar, a handful, etc. Point out that such measures of volume are often more useful than measures of weight.

Encourage students to bring common measures of volume from their homes, including such things as cups, spoons, small boxes, baskets, and pans.

1(b). VOLUMES CAN BE COMPARED WITH EACH OTHER

Children have already worked with the comparison of other kinds of measurements. They have worked with comparison of length and of area, of weight, of time, and of temperature. They should be reminded of these earlier experiences. They should be aware that in this sub-concept, they are working again with a comparison of quantity. This time, they are comparing volumes. Here are some learning activities which can help students understand better the comparison of volumes.

Investigation

How can the volume of a small container be compared to that of a large one?

Materials required
small container
large container

Show children two containers, one obviously larger than the other. Ask them to say how they know one is larger than the other just by a casual

glance. In reply, they will refer to their obvious difference in height and breadth. Ask them to estimate how much larger one is than the other. Ask this in terms of volume. Challenge them to describe a way of finding an accurate answer to the question. With encouragement, some children can suggest that you see how many small jars full of water are needed to fill the large jar. Record the estimates of relative size made by students. Now permit a group of children to make an accurate experimental comparison as suggested above. Point out that such a comparison is useful only for volumes of hollow containers.

Investigation

How can the volumes of two containers be compared?

Materials required
two containers of similar volume but different shape

Obtain two containers whose volume is similar, but whose shape is quite different. Challenge students to say which is the larger. The containers should be deliberately selected so that there will be some difference of opinion about this. Through discussion, help students to discover that they can find out which container has the greater volume by seeing which holds more water. If the containers do not hold water without leaking, use sand or pebbles.

Ask children to consider whether all drinking glasses have the same volume. Do all tea cups have the same volume?

1(c). THE VOLUME OF SIMPLE SHAPES IS EASY TO CALCULATE

Most adults know how to measure the size of a simple block-shaped object and calculate its volume. This is done by multiplying the length times the width times the height. All three of these dimensions should be in the same units. Only the simplest cases of volume calculation are of interest here. These are cases of rectangular blocks, such as bricks, or slabs of wood with all angles being right angles. It is not the purpose of this sub-concept simply to teach students to memorize the way of determining the volume of a simple rectangular solid. Rather, it is intended to help students think for themselves about the volume of regular solids. Here are some activities which can help them reach such understandings on the basis of their own thinking.

Demonstration

What is meant by the volume of a rectangular block?

Materials required
straws or straight sticks
soft clay
cellophane or thin cloth or paper

Prepare a 'skeleton' of a rectangular block using straws and clay, as suggested in Fig. 4-39. Help children visualize that this represents just the corner-outline of a brick-like block of material. Help them describe what is meant by the volume of such a block-shaped object. If possible, wrap this 'skeleton block' with cellophane or nearly transparent paper or cloth so as to make the concept of the volume of the block more realistic.

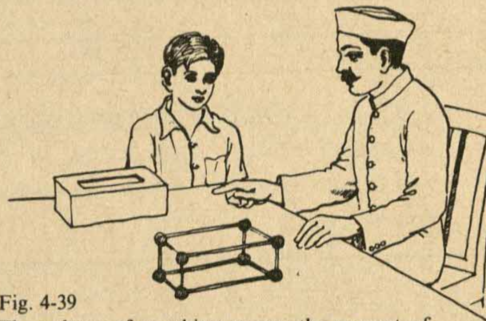


Fig. 4-39
The volume of an object means the amount of space it occupies.

Investigation

How can we measure the volume of a hollow block?

Materials required
small cardboard box
sugar cubes

Show children a small cardboard box perhaps 10 cm long, 6 cm wide, and 3 or 4 cm deep. Ask them to estimate the volume of this box. Most of them will be very confused. Suggest that this might be done by trying to answer the question, 'How many standard units of volume will this box hold?' Suggest that they use as 'units of volume' cubes of sugar, or any other such block which is available in large numbers and is of uniform size and shape. Now help students pack the sugar cubes (or other volume standards) into the unknown box, as in Fig. 4-40. How many are required to fill it? Describe the box as

Fig. 4-40
The volume of a box can be estimated by seeing how many standard blocks can go into it.

having a volume equal to a certain number of sugar cubes. Now measure the inside dimensions of the box, using the side of a sugar cube as the standard length unit. Multiply length times width times depth. How close does the product come out to the volume of the box as determined by counting the number of cubes required to fill it? (If there is a distinct difference between the volume as determined in these two ways, point out that the packed sugar cubes left some unoccupied space in the box.)

Count the number of rows, the number of columns, and the number of layers of cubes in a box of sugar cubes. Multiply these three numbers together. Does this give the total number of sugar cubes in the box?

1(d). THE CUBIC METRE IS THE ACCEPTED STANDARD OF VOLUME

These students are already familiar with metric standards of length, as well as of other dimensions. They are accustomed to using the metre as the standard of length, and the square metre as a standard of area. Now they will have a chance to become acquainted with the cubic metre as a standard of volume. They will also learn about convenient smaller fractions of the cubic metre, just as they learned about centimetres and millimetres, square centimetres and square millimetres. They will also learn about the litre, a very common unit of volume, one particularly used with liquids. The litre is equal to the volume of a cube 10 cm on a side, or 1000 cubic centimetres. Activities such as those which follow can help students become familiar with modern standard units of volume measurement.

Demonstration

What is meant by a cubic metre?

Materials required
twelve slender sticks one metre long
string

Use the string to fasten twelve slender sticks together in the form of a cube. Point out that this is a cube where each edge has a length of one metre. That is, this has a volume of one cubic metre. Invite a child to crouch carefully inside this hollow cube. See how much smaller his volume is than a cubic

metre. Ask children to consider how many of these cubic metres would fit into the entire school room. See Fig. 4-41.

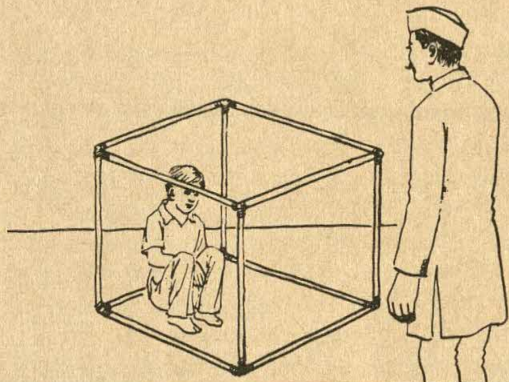


Fig. 4-41
A box, one metre on a side, has a volume of one cubic metre.

Investigation

What is meant by a litre?

Materials required
straws
clay or wax

Help individual children prepare 'skeleton cubes' ten centimetres on each edge. Point out that this is the volume equivalent to a litre. However, a litre of volume need not be cubic in shape—it can be *any* shape. Challenge students to figure how many cubic centimetres there are in a litre (1,000 cubic centimetres equals one litre). How many litres are there in a cubic metre ? (1,000 litres equals one cubic metre.) Also point out that a litre of water or milk weighs almost exactly one kilogram. See Fig. 4-42.

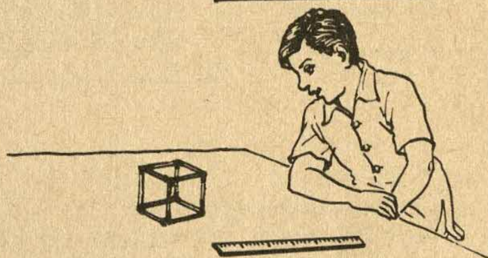


Fig. 4-42
A cube, 10 cm on each side, has a volume of 1 litre.

Discuss the cubic centimetre as a useful volume standard for small objects. Point out that a cubic centimetre of water or milk weighs almost exactly one gram.

2. THE CONCEPT OF DENSITY IS USEFUL IN DESCRIBING MATERIALS

By now class IV students are familiar with the concept of volume. These two properties of an object are tied together in the concept of density. Children are

already familiar with the general nature of this concept, although they usually do not know the proper term—*density*. Also, they may not be conscious of the fact that they use this concept often in daily living. The sub-concepts below are intended to help children draw on their familiar experiences, and also on their understanding of weight and of volume, to develop a meaningful concept of density.

2(a). OBJECTS OF DIFFERENT MATERIALS HAVE DIFFERENT WEIGHTS, EVEN THOUGH THEIR VOLUMES ARE THE SAME

Not all objects having the same volume also have the same weight. A cubic centimetre of iron weighs more than a cubic centimetre of wood. Weight is the force of gravity. The force of gravity acts on each particle in a body. A body having more particles or heavier particles is attracted more by gravity and, therefore, it weighs more. A body having fewer or lighter particles weighs less. Two objects may have the same volume and yet have different weights. Among familiar solids, gold is the heaviest for a given volume. A block of aluminium is lighter than a block of iron of the same size. These kinds of differences can be made clear to students through activities such as these.

Investigation

How do similar sized blocks of different materials compare in weight?

Materials required
brick
small block of iron
small block of wood
pan balance

Show a block-shaped piece of iron or some other metal. Have a piece of wood cut to the exact size as that of the piece of iron. Get a piece of brick and chip it to the size of the other two pieces. Now put the iron piece in one pan and the piece of wood in the other. Compare their weights. Also weigh the brick-piece. Compare their weights with each other. Encourage the students to observe for themselves that though the volumes of all these pieces are equal, the weights are not equal.

Investigation

Can two objects of the same weight have different volumes?

Materials required
pan balance
two identical cans
or jars

Place a can completely full of water on one side of a pan balance. On the other pan place an empty can and enough stones to make the weight the same on each side of the balance. Evidently now the weight of the water in one can equals the weight of stones in the other. Point out this weight equality to the students. Now inquire as to whether these two kinds of material

—the water and the stones—are also of equal volume. Permit students to examine the can containing the stones. They will see that there is considerable space remaining in this can. Make it clear that although the water and the stones have the same weight, this weight is concentrated into a smaller volume in stones than in water. See Fig. 4-43.

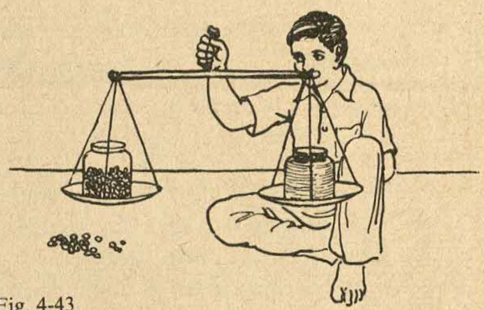


Fig. 4-43
The water and the stones have the same weight but different volumes.

Prepare several packages of identical sizes but containing different materials such as stone, iron, wood, crumpled paper, and the like. Invite children to tell which is which merely by handling the package and judging its weight. Thus they are making their judgments on the basis of weight for a given quantity of volume.

2(b). EQUAL VOLUMES OF DIFFERENT LIQUIDS MAY HAVE DIFFERENT WEIGHTS

The activities suggested above relate to the difference of weight among solids of equal size but composed of different materials. The same general idea is true of liquids. Although the concept is much the same, the techniques of making it clear to students are somewhat different. Here are some activities which are useful in providing an understanding of this sub-concept.

Investigation

Can equal volumes of different liquids have unequal weights?

Materials required
two identical cans or jars
assorted liquids
pan balance

Use a pan balance to compare the weights of two identical cans, each filled with a different liquid. Common and useful liquids to use are water, kerosene, petrol, ghee, syrup, honey, strong salt water. The pan balance or other weighing device used should be as sensitive as possible. With reasonable care some of the very light common liquids like petrol can be shown to weigh less—volume for volume—than some of the very heavy liquids like syrup or very strong salt water.

Investigation | **Are some liquids heavier than others?**

Materials required
common oil
glass jar

Measure out equal volumes of water and a common oil, such as kerosene or ghee. Put the two together in a glass jar, allowing them to mix together as little as possible. The oil floats on the water. Help children reason that the oil is therefore lighter than water. Although they have not yet studied the principle of flotation, they are accustomed to the notion that light things float on water, while heavy things sink. Help them apply this principle to the two liquids, oil and water.

2(c). THE DENSITY OF A MATERIAL IS EXPRESSED IN TERMS OF THE WEIGHT OF SOME STANDARD VOLUME OF THE MATERIAL

Density is defined as weight per unit volume. This definition, although strictly correct, is too brief to be comprehended well by class IV students. It is, however, the ultimate goal toward which this sub-concept is the beginning. Here are some activities which can help students make a beginning toward an understanding of the concept of density.

Discussion | **What is meant by density?**

Recall with children the basic ideas in the activities in the two preceding sub-concepts. Note that in those activities, the attention was focused on the different weights of different materials or objects, even though their volume was the same. That is, attention was on the *weight for a given unit of volume*. It makes no difference exactly what that volume is, so long as the volume is the same for all the objects and materials being considered. State this again using different sets of words. Invite students to use their own words to describe this. Make frequent use of phrases like 'weight for a given amount of volume' or 'weight per standard unit of volume'. This is the core of the concept of density.

Describe the density of some common materials to children, such as :

water	1 *kilogram per litre or one gram per cubic centimetre*

petrol (about)	700 *grams per litre or* 0·7 *grams per cubic centimetre*
iron (about)	10 *grams per cubic centimetre*
rock (typically)	2 *or* 3 *grams per cubic centimetre*
wood (typically)	0·3–0·8 *grams per cubic centimetre*

Point out that all these figures use the same unit for the volume of the material, and that this unit is a standard part of the metric system of measurements.

2(d). WATER IS USED AS THE STANDARD OF DENSITY

When the metric system was developed about the beginning of the 19th century, it was intended that things would turn out so that water would have a density of one kilogram per litre, or one gram per cubic centimetre. This is still true for all practical purposes. It is a convenient reference point for density, because it is a simple number (1) applied to a common material (water). Here are some activities which can help students see the convenience of expressing the density of water as one gram per cubic centimetre.

Demonstration

In what different ways can the density of water be expressed?

Materials required
common containers
balance

Weigh water in common volume quantities such as a cup, a spoon, a cubic inch, a cubic centimetre, and a drop. If these measurements are difficult, the same idea can be given to the students through drawings.

Typical values for the above volumes are :

cup	200 grams
spoon	4 grams
cubic inch	just over 16 grams
cubic centimetre	1 gram
drop	1/20 gram

Figures such as these will help children see that the cubic centimetre is a very convenient 'standard unit of volume' for use with the concept of density.

Discussion

Why is water such a useful standard for density?

Consult the data for the last suggested activity under the sub-concept 2(c). This time, in the discussion, ask students which of the materials would

make the most convenient standard for density. The simplicity of the number involved (1) will lead them to select water as a useful standard of density.

3. BECAUSE LIQUIDS HAVE WEIGHT, THERE IS FORCE WITHIN THEM

Class IV children have accumulated considerable familiarity with liquids. Some of this they have acquired in the ordinary activities of daily living; some they have learned in earlier classes. Whatever the source, these students do know that liquids can be poured, and that they take the shape of their container. They know that liquids dissolve many other materials. They know that some liquids solidify when they are cold enough; in the case of water, they also know that this liquid changes to a vapour under proper conditions.

Now they are in a position to learn some of the other characteristics of liquids. In particular, attention is here focused on the pressure which exists within liquids. Only the simplest cases are considered here —those cases where pressure is exerted due to the liquid's own weight. These materials are of intrinsic value and interest. Furthermore, they provide a groundwork for related materials in class V, materials related to the behaviour of floating objects, and to Archimedes Principle. The sub-concepts which follow are organized to help students acquire these basic understandings about pressure in liquids.

3(a). THERE IS FORCE BENEATH THE SURFACE OF A LIQUID

Any person who has been swimming to a depth of two or three metres knows that there is noticeable pressure that deep in the water. This pressure can be felt as a mild pressure on the ears. For most people this pressure becomes so painful at a depth of about five metres that they can go no deeper. 'Frogmen' and deep-sea divers must make some kind of provision for this pressure. Most class IV students have never been a few metres under the water, and very few of them are likely to do any deep-sea diving. Such personal experiences being lacking on the part of students, teachers should arrange other activities to help children comprehend this sub-concept. Here are examples of such activities.

Investigation | **Is there force beneath the surface of water?**

Materials required
cellophane or thin plastic bag
jar or tank at least 30 cm deep

Help a student wrap his hand very lightly with a thin plastic bag or with a layer of cellophane or other thin, clear plastic. The wrapping should be very flimsy. It should be such that air can easily pass in or out at the wrist, as

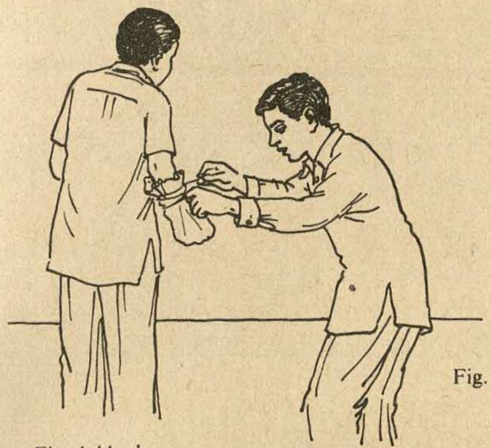


Fig. 4-44a

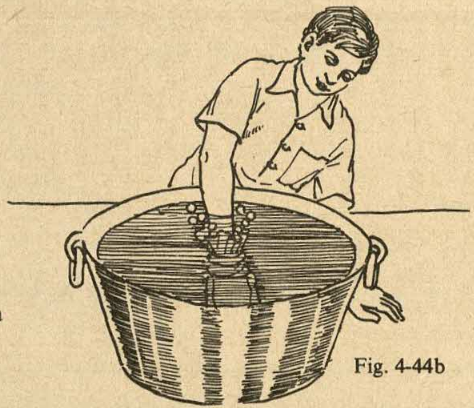


Fig. 4-44b

Fig. 4-44a, b
Air comes out of the plastic bag because of forces present under water.

shown in Fig. 4-44. Now have him lower his wrapped hand into a jar or tank of water—as deep as he can put it. The pressure of the water forces much of the air out of the wrapping where it is loose around the wrist. The student can feel the plastic clinging tightly to his hand as the water forces it inward. Permit the student to describe this sensation to the other children in the class.

Investigation

What evidence is available to show that there exists force beneath water?

Materials required
large jar, preferably glass
thin plastic bag

Fill a thin plastic bag with air and close the opening. However, the opening must be very lightly closed, so that air can leak out if there is pressure on the bag. Now lower this inflated bag into a jar of water. Encourage the class

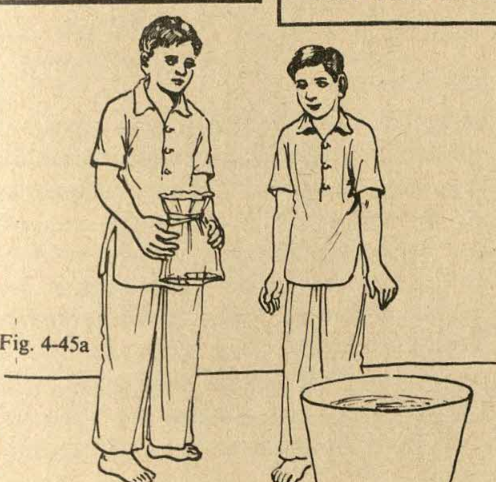


Fig. 4-45a

Fig. 4-45a, b
Pressure beneath the water forces air out of this plastic bag.

to note that *something* is forcing the air out of the bag, as in Fig. 4-45. That *something* is the force which exists beneath the surface of the water.

Fig. 4-45b

Use a nail to make a small hole in the side of a tall tin can, quite near the bottom as in Fig. 4-46. *Fill the can with water, and observe how the water does not simply fall, but literally squirts from the hole. This squirting is caused by a force within the water in the can.*

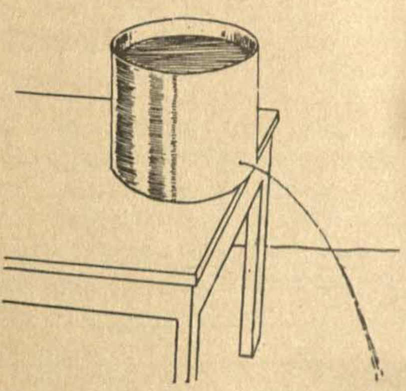


Fig. 4-46
The water does not simply fall from the hole; it squirts out due to pressure within the water.

For Better Understanding

Children and many adults use the terms 'force' and 'pressure' interchangeably. This is not a serious error at this stage of understanding. The fact is, however, that force and pressure are not the same. Force is already familiar to students. It is often called a 'push' or a 'pull', and it is exerted by muscles or machinery, or often by gravity. The force beneath the surface of water being discussed in this major concept is due to the weight of the water—hence due to gravity. This force could easily be measured in familiar force units, such as gram or kilograms. For example, the total force on the bottom of an ordinary can containing a litre of water is one kilogram. This must be the case, since the force is produced by the water's weight, and since the litre of water weighs one kilogram.

Pressure, however, is a somewhat diffe-

rent term. Pressure is defined as force per unit of area. Hence it would be expressed in term such as kilograms of force per square metre, or grams of force per square centimetre. Notice that the concept of pressure is related to the way a force is distributed over a given area. Suppose the ordinary can mentioned above has a bottom whose area is 50 square centimetres. Then the total force of one kilogram would be distributed over that area. Hence, the *pressure* would be 1 kilogram (1,000 grams) of force on 50 square centimetres of area, or 20 grams of force on each one square centimetre. This pressure would then be described as 20 grams of force per square centimetre, or 20 gf/sq. cm.

This is too much detail for class IV students. In most cases in this major concept, the statements are rigorously true regardless of whether the term 'force' or the term 'pressure' is used. If students do not raise the question, the teacher may properly ignore the difference between force and pressure here. It is more important that students become familiar with the general idea that there is force (and there is also pressure) beneath the surface of water.

3(b). AT ANY ONE DEPTH THE FORCE WITHIN A LIQUID IS EXERTED EQUALLY IN ALL DIRECTIONS

In the previous sub-concept, students have learned that there is a force (and there is a pressure) beneath the surface of water. They know that this force is due to the weight of the water. Consequently, it is not difficult for them to see how this force is produced downward on the bottom of the container holding the liquid. It is more difficult, however, for them to realize that this force is also exerted in other directions, including sidewards and upwards, as well as downwards. Here are some activities which can help students realize that at any one depth the pressure is equal in all directions.

Investigation

In what direction is under water force exerted?

Materials required
large jar, preferably of glass
round balloon

Fig. 4-47a

Inflate a small round balloon. Now lower it as deep as possible into a container of water while the students observe. Point out that if the pressure beneath the water is exerted downward only, the balloon will become flatter. But if the pressure is exerted in all directions, the balloon will become

slightly smaller, but will retain its original shape as in Fig. 4-47. Students' own observations will readily verify that the balloon is not flattened. Hence, pressure beneath the water must be exerted in all directions.

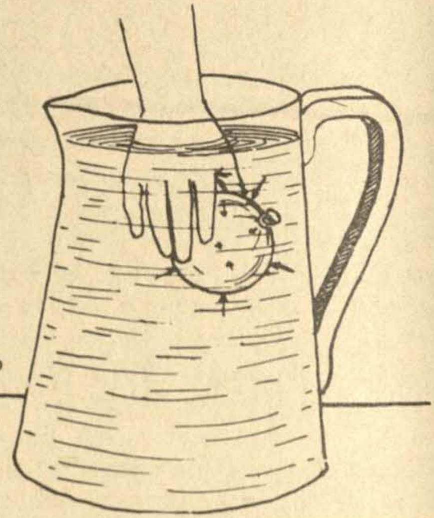


Fig. 4-47b

Fig. 4-47a, b
The balloon is made smaller due to water pressure pushing on it in all directions.

Repeat the investigation associated with Fig. 4-45 *above. This time have the experimenter note whether the pressure he feels on his hand beneath the water seems to be only from above, or from all directions.*

Again put water in a tall can which has a small hole punched in the side near the bottom. See Fig. 4-46. *The fact that the water squirts out* sideways *is an indication that the pressure at that depth inside the can is sideways.*

3(c). THE PRESSURE WITHIN A LIQUID INCREASES WITH THE DEPTH OF THE LIQUID

Students already know that the pressure within water is due to the weight of the water. Accordingly, it is not difficult to see that the deeper the water is, the greater is the pressure, since the deeper the water, the more weight of water there is above a given point. It is, of course, useful to reason with students along these lines. The learning, however, can hardly be effective unless it includes meaningful first-hand experiences on the part of the students. In many cases, it is useful to begin with the observations, then explain the significance of the observations along logical lines such as those above. Here are some suggested activities through which students can make the necessary first-hand observations.

Investigation

How does water pressure vary with depth?

Materials required
tall tin can
nail (to punch holes in can)

Punch four or five holes along the side of a tall empty tin can, as suggested in Fig. 4-48. While children cover the holes with their fingers, fill the tin can. When the fingers are removed, the water squirts out of the holes as shown in the figure. Notice that the lower the hole, the more vigorously the water squirts out. This is because the water is deeper over the lower holes, therefore, the pressure there is greater.

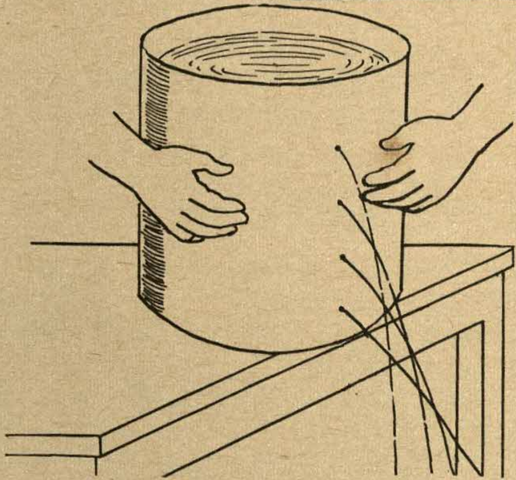


Fig. 4-48
Water pressure increases with depth; hence water squirts out more strongly from the deeper holes.

Investigation

How do air bubbles vary in size as they rise through water?

Materials required
deep jar, preferably of glass
long flexible tube or piece of pipe

Fill a deep glass jar with water. A giant bottle—the kind used in some drinking supplies—is excellent. Use the tubing to introduce a small bubble of air into the bottom of the jar. The bubble rises. Carefully observe its size as it rises. It becomes larger as it gets nearer the top, as in Fig. 4-49. It gets larger because the pressure near the surface of the water is less, and therefore, permits the bubble of air to expand.

Fig. 4-49
Water pressure increases with depth; therefore, the air bubbles are smaller when they are deeper in the water

Discuss the heavy construction of submarines which go to great depths. This strength is needed to withstand the pressure at great depths.

Display pictures of dams, showing that they are thicker at the bottom than at the top. This is necessary because the pressure at the bottom—where the water is deeper—is greater than that at the surface.

3(d). FLOATING OBJECTS ARE HELD UP BY THE FORCE WITHIN WATER

Everyone is aware that some objects float in water. Often they explain this simply by saying that 'if an object is lighter than water, it floats; if it is heavier, it sinks'. This is not an accurate explanation. Students in this class already know that it can be predicted whether or not an object will float. This prediction is made in terms of density—the weight per unit volume, of the object. If an object has an average density (including all its air spaces) less than water, it floats. If the object's average density is more than that of water, it sinks. Even this more accurate discussion of floatation, however, does not explain what force holds a floating object up.

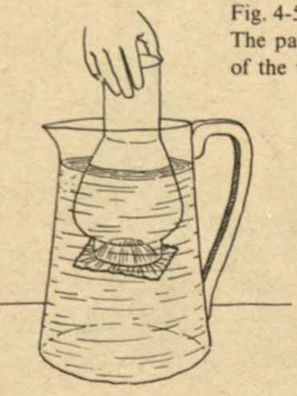
Children know that material objects have weight. They also know that some force must support this weight, or else the object will fall. Here are some activities which can help children understand what force keeps a floating object from sinking.

Investigation

What force could support a floating disk of wood?

Materials required
glass lamp chimney
disc of wood about 2 cm thick and same diametre as chimney
large glass jar
heavy paper

Fig. 4-50
The paper is held in place by the upward force of the water.



Place a piece of heavy paper over one end of a glass lamp chimney. Lower it into the water as shown in Fig. 4-50. Note how the paper is held in place. If the paper is not too stiff, it can be seen to bulge upward due to the force within the water beneath it. Call this

to the attention of students. Now remove the lamp chimney and place a disk of wood floating in the water. Have students notice how deep is the lower surface of the disk. Help them to understand that the water exerts an upward force (called a buoyant force) on the bottom of the disc, even though it is not so deep as the lamp chimney was. This is a force of the same nature as that which held the paper in place at the lower opening of the glass lamp chimney.

Let children try to push a large log or block of wood under water. They can feel with their own arms the upward force exerted by the water on the wood.

For Better Understanding

It is helpful for teachers to realize a bit more about the forces involved in floatation. A block of wood has weight. This weight is a downward force. If the wood is not to sink, it must be supported by an upward force equal to the weight of the wood. The deeper the wood goes into the water, the greater is the force (and the pressure) upward on its lower surface. Therefore, the wood sinks until its bottom is deep enough so that there is exerted on it a buoyant force equal to the wood's weight.

If the block of metal is used instead, it will sink completely under water. Under these conditions the upward force on its bottom is still smaller than the weight (downward force) of the metal. So the buoyant force does reduce the apparent weight of the metal. It is for this reason that heavy stones *feel* lighter when they are handled under water. The upward buoyant force of the water makes them *appear* less heavy. This will be taken up at the student level in class V of this same unit.

3(e). FORCES WITHIN LIQUIDS CAN BE UNDERSTOOD IN TERMS OF PRESSURE

Thus far in this major concept, the terms 'force' and 'pressure' have been used quite loosely in these pages. There is, however, an important difference. (see 'For Better Understanding' on pages 20-21). This is a good point at which to introduce children to the concept of pressure. Pressure is a concept involving both force and area. Pressure is defined as *force per unit area*. Pressure may be thought of as the extent to which force is concentrated within a small area. Force can be expressed in units such as kilograms or grams. Pressure is expressed in such terms as kilograms of force per square metre, or grams of force per square centimetre. Here are some activities to help children better understand the concept of pressure.

Investigation

What is the difference between force and pressure?

Materials required
two tin cans of different size, each punched with a hole near the bottom
tubing to fit the punched holes

Close the holes in the cans, and fill them to the same depth of water as in Fig. 4-51. Discuss with the class the *force* on the bottom of each can. Remind them that force is dependent on the weight of the water above. Since one can is larger than the other, the weight of its water will be more. Hence the force on the bottom of the larger can will be greater than the force on the bottom of the smaller can. Get the class to agree on this.

Now ask the students to predict what would happen if the two cans were connected together by the tubing, as shown in the sketch. Remind them that this is a connection between a place where the underwater force is high and another place where the underwater force is low. Many students will be tempted to predict that water will flow from the large can to the small one because of the difference in underwater force. Some will be uneasy about this, because they realize that water seeks its own level. If this is the case, there should be no flow of water! What will actually happen? Once children have made their predictions, this should be tried out experimentally. It will be observed that there is no flow of water from one can to the other.

The reason there is no flow is that the total force of the water *over the*

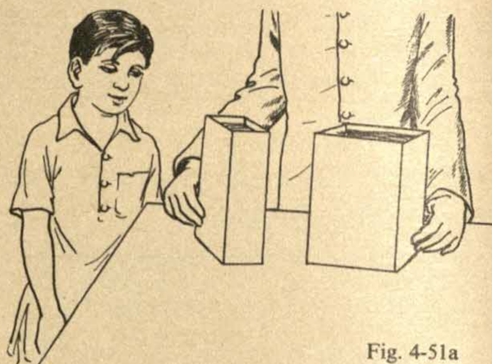


Fig. 4-51a

Fig. 4-51a, b
Although the force on the bottom of these two cans is different, the pressure (force for unit area) is the same Therefore, water does not flow from the larger can to the smaller can when they are connected

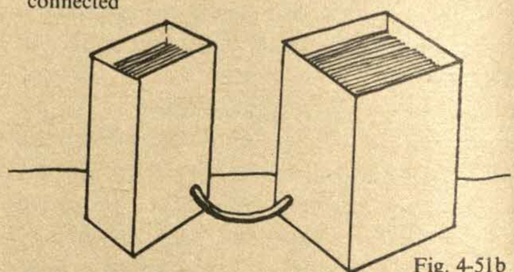


Fig. 4-51b

area of the tubing hole is the same in the one can as in the other. True, there is more total force on the bottom of the large can than on the bottom of the small one. But in the former case, this force is distributed over a larger area. The force on a given unit of area is the same. Hence, the force on the area of the hole in one end of the tubing is the same as the force on

the area of the hole in the other end of the tubing. That is, the pressure is the same in both cases. Hence there is no flow.

Encourage students to discuss this at considerable length. Make sure they use the terms 'force' and 'pressure' often—and properly. (If the equipment for this investigation cannot be obtained, show it simply by drawing pictures and carrying on the same discussion with the class. Only the experimental verification of predictions will be missing from this 'imaginary treatment' of the investigation.)

Discussion

How are 'underwater force' and 'underwater pressure' related?

Make a sketch for students, something like that of Fig. 4-52. Notice that the two containers are each 10 cm deep. One has a bottom which is 4 cm square; the bottom of the other is 8 cm square. Thus the areas of the two bottoms are 16 cm^2 and 64 cm^2 respectively, a ratio of 1:4. Remind students that water weighs one gram per cubic centimetre. Guide the discussion as follows:

What is the weight of water in the smaller container? (160 gf)

What is the total force on the bottom of the smaller container? (160 gf)

What is the weight of water in the larger container? (640 gf)

What is the total force on the bottom of the larger container? (640 gf)

What is the pressure (force per unit area) at the bottom of the smaller container? (160 gf/16 cm^2 or 10 gf/cm^2)

What is the pressure (force per unit area) at the bottom of the larger container? (640 gf/64 cm^2 or 10 gf. cm^2)

Note that the pressure at the bottom of the two containers is the same, regardless of the area of their bottom. The pressure is the same because the depth of water is the same.

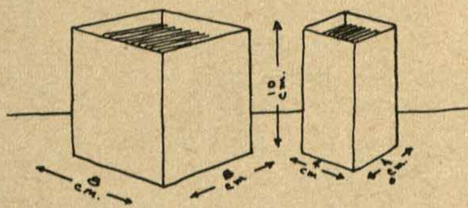


Fig. 4-52
Although the force on the bottom of these two cans is different, the pressure (force for unit area) is the same.

For Better Understanding

It is true, of course, that the pressure at the surface of water is not zero. There is pressure at the surface due to the atmosphere. The pressure of the normal atmosphere is about one kilogram (1,000 grams) of force per square centimetre. Therefore, the total pressure (called absolute pressure) at a depth of 10 centimetres is really about 1,010 gf/cm^2. It is quite common, however, to speak of the pressure in a tyre, or beneath the surface of water, as pressure *more than atmospheric pressure* (called relative pressure). This is the pressure actually shown on tyre gauges, pressure cookers, steam boilers etc. If students do not raise this point, it is probably best not to confuse them with it at this time. The logic of the foregoing discussions is just as valid whether done in terms of relative pressure (as was done) or in terms of absolute pressure.

3(f). THE ATMOSPHERE EXERTS PRESSURE

Students have already learned (in Unit 2, 'Air, Water and Weather') about air pressure. The term pressure is thus common to them. They realize that pressure can be exerted not only by water, but also by air. They know that air has weight, and that atmospheric pressure is caused by the weight of the air above. They have been told that the pressure of the normal atmosphere is approximately one kilogram of force per square centimetre. This is a good place to refresh their memories concerning air pressure, and to relate the cause and effects of air pressure to those of water pressure. Through activities like these the teacher can help the students in these understandings.

Discussion

How great is air pressure?

Remind students of the cause of atmospheric pressure. Remind them that the pressure is caused by the weight of the air above the surface of the ground. If they knew the weight of a column of air one centimetre square and extending from the ground up to 'outer space' as suggested in Fig. 4-53, they would know the pressure of the atmosphere. The pressure of the air has been measured countless times. Although it fluctuates from hour-to-hour and day-to-day, typical sea level air pressure is known to be about 1 kilogram of force per square centimetre (1 kgf/cm^2).

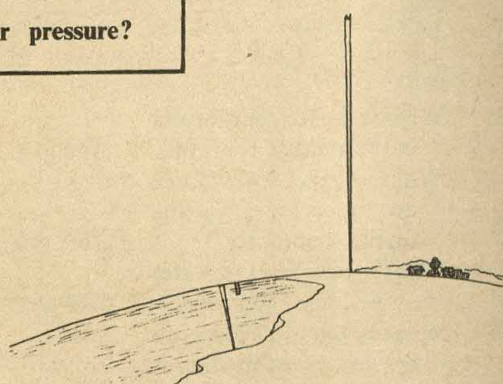


Fig. 4-53
Atmospheric pressure is caused by the weight of the air above. Beneath the water the pressure is increased by about 1 kgf/cm^2 for each 10 metres of depth.

Discuss with children how this compares with the relative pressure within normal containers of water. How deep

would one have to go in water to reach a place where the pressure is 1 kgf/cm^2 more than at the surface? (1,000 cm or 10 metres). This means that at a depth of 10 metres, the skin diver is subjected to a total of twice the ordinary pressure, since down there the pressure is 1 kgf/cm^2 more than atmospheric pressure, or a total of 2 kgf/cm^2. What would be the *total* (absolute) pressure at 100 metres depth? (11 kgf/cm.)

Remind children of what they already know concerning the operation of a lift pump, of how one sips water through a straw, and the way a siphon works. Remind them that all these operations depend on the existence of air pressure.

For Better Understanding

The work in this major concept was specifically concerned with pressure within water and within the atmosphere. Actually the principles involved here apply to all liquids and to all gases—that is, to all fluids. In all cases, the pressure depends on the weight of a column of fluid above, and the pressure at any point is exerted equally in all directions. In most liquids, the pressure is directly proportional to the depth. In large layers of gas, like the atmosphere, the relationship is not simple. This is because air is compressible, while water is virtually incompressible. As a result, layers of air near the earth's surface, being under greater pressure, are compressed, and therefore more dense. The pressure of the atmosphere at about 6,000 metres is half that at the surface, at 12,000 metres it is about one fourth that at the surface. Some traces of air are known to exist even at altitudes of more than 150 kilometres. See Fig. 4-54.

Fig. 4-54
The pressure of the atmosphere decreases with altitude.

4. MANY SIMPLE MACHINES CLOSELY RESEMBLE THE INCLINED PLANE OR THE LEVER

In daily life people use many types of simple machines. The purpose of all of them is to make work easier for human beings. A pair of scissors or pliers is an example of such machines. These simple machines are levers. A prying bar, a geared wheel, a

wheelbarrow, and a pair of tongs are also examples of levers. A stair-case, a road leading up a hill, a plank of wood used to load a truck, a jackscrew and ordinary wood-screw are much like the inclined plane. These are also simple machines.

4(a). A WEDGE MAY BE THOUGHT OF AS TWO INCLINED PLANES BACK TO BACK

A wedge is an example of inclined plane. A wooden wedge is often driven under a very heavy object to raise it. When a long log of wood is being split, a wedge is inserted between the two parts to separate them further. The edge of a penknife or a razor blade or a chisel is sloping on both sides. It is a wedge. It helps the user to cut a thing easily. Class IV students have already learned about the inclined planes as simple machines. They can understand the wedge—another simple machine—better if they regard it as a variation of an inclined plane. Activities such as the following can help students better understand how a wedge is related to an inclined plane.

Investigation

How is a wedge used?

Materials required
wood wedge
wood block
heavy stone

Obtain a wedge made of wood from a local carpenter. Also get a rectangular piece of wood of the same size as that of the wedge but without sloping planes. Get a large piece of stone and ask children to try to lift it. They will find that it is too heavy. Let them next try to put the rectangular piece under the stone. This cannot be done too. Then they can try the wedge and see that it goes under the stone. If they drive the wedge farther under the stone, they will notice that this raises the stone. See Fig. 4-55.

Fig. 4-55a

Fig. 4-55b

Fig. 4-55a, b
A wedge can be driven into an opening to produce great force

Let the students try cutting a potato, first with an ordinary piece of iron and then with a penknife.

Let the students use a carpenter's chisel to cut a piece of wood.

In relation to the above activities, discuss with the children that the wedge does not supply energy to do the task; the user supplies the energy.

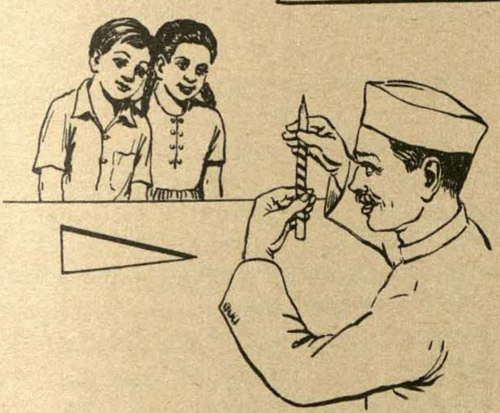
4(b). A SCREW MAY BE THOUGHT OF AS AN INCLINED PLANE WRAPPED ROUND A ROD

The ordinary screw is a form of inclined plane. If a paper triangle is wrapped around a rod, the side of the triangle running spirally round the rod represents the thread of the screw, as suggested in the sketch. Many common mechanical devices are based on the principle of the screw. Children can understand screws better if they realize that they are closely related to the inclined plane. The following activities will help students understand that the screw is a variation of the inclined plane.

Demonstration

How does a screw resemble an inclined plane?

Materials required
paper
red ink or crayon
scissors
pencil



Cut a right-angle triangle out of a paper. Mark the hypotenuse with a heavy line. Hold the pencil along the smallest side of the triangle. Wrap the triangle round the pencil. The marked hypotenuse should be on the outer side so that it can be seen winding around the pencil, as in Fig. 4-56. The heavy line around the pencil illustrates the threads of the screw.

Fig. 4-56
A screw may be thought of as an inclined plane wrapped around a rod

Examine samples of wood screws and bolts brought to class. See how they resemble an inclined plane wrapped around a rod.

Discuss with children how a stairway is an inclined plane with 'place for the feet'. From this point of view, challenge them to say how a spiral stairway is like a screw.

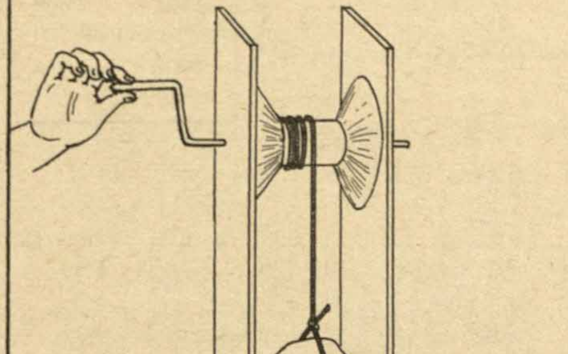
4(c). A WINDLASS MAY BE THOUGHT OF AS A CONTINUOUSLY MOVING LEVER

A windlass is a very common kind of simple machine. One key part of a windlass is a drum which winds in rope or chain or string, and which also can unwind it under controlled conditions. The other key part is a lever arm or crank which permits one to turn the drum. Windlasses are often used to hoist and lower elevators and to lift heavy loads at shipyards and large factories. Even a common fishing reel may be thought of as a small windlass. A simple windlass is often used to lower a bucket into a well and to raise the water out.

The windlass can be best understood by thinking of it as a variation of a simple lever. Here are some activities which can help students see a windlass in this useful way.

Construction | **Can we make a model windlass?**

Materials required
thin wood
nails
stiff wire
empty spool
string
simple hand tools



Help children prepare and use a working model of a windlass as suggested in Fig. 4-57. If necessary, get some help from a local carpenter. The crank handle is made by bending stiff wire into the shape shown. Then this is inserted through one of the side-supports, through the spool, and then through the other side support. The

Fig. 4-57
It is easy to make a working model of a windlass.

special bends in the stiff wire are to keep the spool from slipping around the wire, which acts as the drum axle. Now wind string around the spool (drum) as shown in the figure. Permit students to use this model wheel and axle to see how such a device actually operates.

Visit a well where the water is hauled up and the empty bucket lowered by means of a windlass.

Borrow a fishing reel from a fisherman. Show students how this simple machine helps the fisherman wind in his line very quickly.

Discuss the above machines with children. Ask them whether or not the wheel and axle actually supplies the energy to do the job. Help them develop for themselves the idea that the wheel and axle does not work by itself, it merely helps the user to do work.

4(d). A PAIR OF MESHED GEARS MAY BE THOUGHT OF AS ONE SET OF LEVERS PUSHING AGAINST ANOTHER

Imagine two wheels with their rims pressed firmly together. When one wheel is turned, it makes the other one also turn. But what if the one wheel slips against the other? This can be prevented by cutting notches into the edge of each wheel, and arranging them so the teeth of one wheel mesh with the teeth of the other. Now they will not slip. Motion can be reliably transferred from one wheel to the other. This is called a *set of meshed gears.*

Meshed gears are a very common type of simple machine. They can be best understood if they are thought of as special forms of levers. Here are some activities which will help children understand the operation of meshed gears better because they are considered as variations on a system of levers.

Demonstration

How are meshed gears like a system of levers?

Materials required
heavy cardboard
two nails
thin strips of wood
scissors

Prepare two cardboard models of gears, as suggested in Fig. 4-58. One should be about twice the diameter of the other. The teeth should be cut care-

fully, so that they are very even in spacing and in depth. The two wheels are now mounted to a board—or fastened to a smooth area of the ground, with nails through their centres. If they are carefully made, the teeth will mesh, and turning the smaller gear wheel will easily make the larger one also turn.

Now prepare two long thin sticks. One of them should be long enough to extend from the tip of a tooth on the small gear wheel to the tip of the opposite tooth on the same wheel. In a similar way, the other stick should be long enough to reach from the tip of a tooth on the larger gear wheel to the tip of the opposite tooth on the same wheel, as shown in the sketch. Place these sticks as shown so that one end of each stick is on a tooth which is actually meshed with the other gear. Help children to realize that only the teeth which are meshing are like the ends of these two sticks. In this way, the meshed gears are something like two levers, so arranged that the moving end of one lever pushes on one end of the other lever.

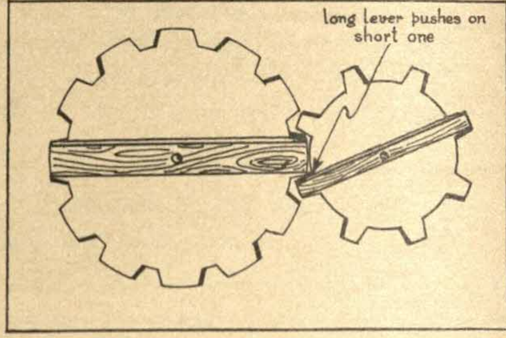


Fig. 4-58a

Fig. 4-58a, b
Meshed gears may be thought of as one set of levers pushing against another.

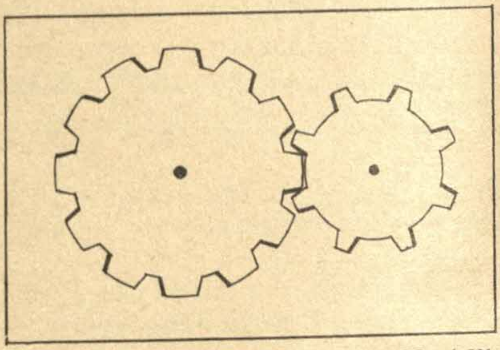


Fig. 4-58b

Demonstration

What can we learn about the gears in a clock?

Material required
large clock

Remove the back of a large clock and show the gears to the students. They can see that they are of different sizes. Yet each gear meshes with at least one other—often with two other gears. When the clock is running, some of the gears turn much more slowly than others. Encourage children to study the clock mechanism. If they are patient, they can see how the force is transferred from the spring or the weights (the source of the force and energy which makes the clock go). It is transferred through a series of

meshed gears to the hands, which are then turned around at the proper speed to make the clock a useful timepiece.

Take the class to see simple arrangements to gears in the community. These can be found in a sugarcane cutter or in a crank-operated cane press. Some village wells are operated by a large but useful set of meshed gears. Help children appreciate how simply they operate, yet how sturdily they must be constructed.

4(e). A SINGLE PULLEY SIMPLY CHANGES THE DIRECTION OF A FORCE

When a person pulls on a rope, he often applies that force with the aid of a single pulley. The pulley can turn on its own axis as the rope moves over it. Other than that, the pulley is fixed. The important thing that this pulley does is to permit the rope's pull to change direction. Pulleys of this kind are used at the top of a flagpole, for rolling chicks up and down on their hangings, and at many other places. One of the most common uses of a single fixed pulley is at the top of a well.

A single fixed pulley is a simple machine. It can be understood best as a variation on a lever. Here are some experiences which can help students comprehend this important viewpoint about the operation of a single fixed pulley.

Demonstration

How is a single pulley like a lever?

Materials required
wood and nails to make simple lever and its support
string
stones for weights

Pivot a straight stick to make a lever with equal arms, as shown in Fig. 4-59. Support this on a fulcrum made of three pieces of wood, as shown in the figure. Tie a string to each end of the lever. Tie a brick or stone to one of these strings. Now permit a child to raise the brick slightly by pulling down on the string fastened to the other end of the lever. Ask him and the class how far he could lift the stone through this lever mechanism. They will readily

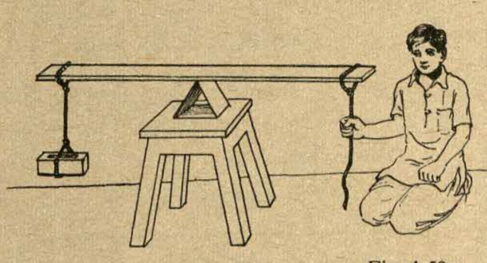


Fig. 4-59a

Fig. 4-59a, b
A single pulley may be thought out as a continuously moving lever.

agree that the device can lift the brick only through a limited distance.

Use a sketch something like that shown to suggest how a single equal-arm lever can be thought of as the diameter of a single fixed pulley. But this pulley is a modified lever which has no limit to how far things can be lifted.

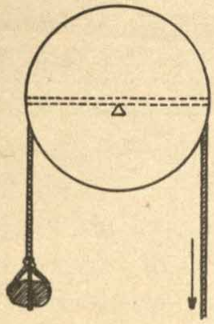


Fig. 4-59b

Investigation

Does a single fixed pulley increase force?

Materials required
spring balance
fixed pulley
string
stone

Prepare a spring balance and a single pulley. Tie a string to a stone and lift it by the spring balance. Record the weight. Then fix the pulley to some support. Take the end of the string, which is fastened to the stone, over the pulley and tie the other end to the hook of the balance, as in Fig. 4-60. Now pull the balance till the stone is lifted above the floor. Let students read the balance now. The force in both the trials will be found to be the same.

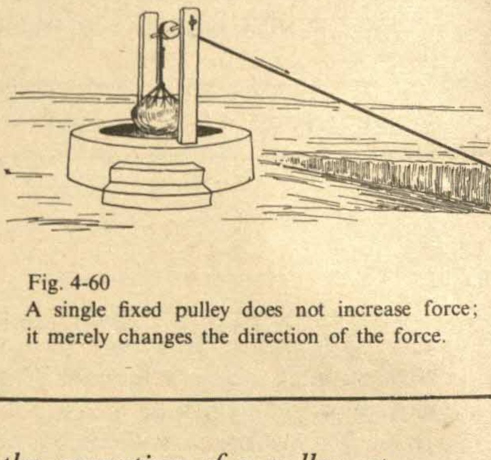


Fig. 4-60
A single fixed pulley does not increase force; it merely changes the direction of the force.

Help children observe the use and the operation of a pulley at the top of a flagpole.

Take children to visit a village well where a rope strung over a pulley is used to lower a bucket and raise the water.

In both the above cases, point out that the pulley does not increase the force applied—it merely changes the direction in which it is applied.

For Better Understanding

It is not the purpose of the work on simple machines at this class level to have children analyse their operation in detail. Indeed, there are perhaps no more than three main ideas in the total major concept which ends here:

(a) Almost all simple machines can be thought of as variations on either the inclined plane or the lever.

(b) Simple machines do no work; people do work with simple machines. The user must supply the energy to perform the task at hand.

(c) Most simple machines permit a small force from the user to exert a large force on some object.

At later class levels, students will learn more about the theory of simple machines. In the event that a few students should ask, here is some additional information for the teacher:

In a simple machine, the user does some work on the machine. He does this by exerting a force through a distance. This work and this force are thought of as being at the 'input' of the machine. Hence, they are called force input (F_i) and distance input (D_i). Multiplied together, these two figures give the work input W_i. that is,

$$F_i \times D_i = W_i$$

The machine, on the other hand, does work on an object. This may be thought of as work output, and is accomplished by an output force (F_o) acting through an output distance (D_o). In this case, $W_o = F_o \times D_o$

Most simple machines use a small force input to produce a large force output. However, the work (energy) involved in the output work cannot exceed the input work. This must be the case since the input work (energy) is the *only* source of energy for the entire system. The machine itself is not a source of energy.

For this to be true, the input distance must be large if the input force is small. Similarly, the output distance must be small if the output force is large. Only in this way can the input energy be as large as the output. Accordingly one can expect in most ordinary simple machines that there will be a small input force acting through a large input distance. This will produce a large output force acting through a small output distance.

5. HEAT IS A USEFUL FORM OF ENERGY

So far in this syllabus, students have given serious attention only to one form of energy. This is work, the exerting of a force through a distance. This is often called mechanical energy. There are many other energy forms, also. These include solar energy, electric energy, light energy, and chemical energy, among others. Here is the place where

class IV students begin their serious study of another form of energy beside work. This other energy form is heat.

Students are, of course, very familiar with heat and with temperature. They have hundreds of daily-life experiences with such things. They have also encountered heat and temperature elsewhere in this Teacher's Handbook. This is particularly true in Unit 2, 'Air, Water and Weather' and in Unit 5, 'Matter and Materials'. Usually, however, they have not been concerned with heat as *energy*. The sub-concepts which follow are intended to give fourth class students a simple but accurate introduction to heat, not simply as a personal sensation, but rather as a form of energy.

5(a). HEAT IS USEFUL TO MAN IN MANY WAYS

Energy in the form of heat has been used by man for a very long time. It is used for cooking food, for heating water, for keeping a home warm, for extracting metals from their ores. The state of matter can be changed by supplying heat or removing it. Heat solid ice and it changes to liquid water; heat it further and it becomes a gas. Here are some activities which can help students appreciate the great variety of uses man makes of heat, and how very dependent man is on this form of energy.

Discussion **How much do we use heat?**

Discuss with the class the various uses we make of heat. Begin by asking them when last they used heat. When will they next use heat for some purpose? Are they using any heat right now? For what kinds of purposes do we use heat? What would it be like to live without any source of heat? How long could people live without heat?

Discuss with children what is meant by 'cold'. Help them to realize that although the word 'cold' has the opposite meaning of the word 'heat', they are not really opposite phenomena. Rather, cold is simply the absence of heat.

Throughout these discussions, be careful to use the noun 'heat' and not the adjective 'hot'. Remind children that heat *is* something *(a form of energy) which comes from the sun or from fire or elsewhere. But* hot *is a word which describes the condition of something or some person.*

Discuss engines which operate by heat, including steam engines, gasoline engines, jet engines, and rocket engines.

5(b). HEAT IS OBTAINED FROM VARIOUS SOURCES

There are many sources from which man obtains heat. Heat from fire and heat from the sun are very common examples. In addition, heat can be obtained from electricity—and it can be obtained from nuclear reactors. Heat can also be obtained from movement, as in the case of the heating effect of friction. A closely related situation is that of obtaining heat by compressing materials, such as air. In this sub-concept, students will have an opportunity to see first hand many of these sources of heat. Furthermore, they will see what these sources have in common, and thus acquire a better idea of what heat really is. Here are some activities which can help students thus improve their understanding of the sources of heat, and of the nature of heat itself.

Discussion

What are the more common sources of heat?

In an earlier discussion, students were urged to consider the occasions on which they use heat. Now they can be encouraged to think about the sources of this heat. The most common examples will be heat from the sun, heat from fires, and heat (body warmth) from food. Students will also think of heat from electricity (as in electric heaters) and heat from nuclear reactors. If they do not suggest it, call the students' attention to heat which comes from movement. Heat from rubbing (friction) will be one common example. Remind them that a piece of metal bent vigorously often becomes warm. Also remind them that the barrel (cylinder) of a cycle pump becomes warm when air is compressed in it during the pumping process.

Investigation

Can we get heat from friction?

Materials required
small piece of wood
sandpaper

Permit a child to use a piece of sandpaper to rub a small piece of wood very vigorously. Very soon he will notice that the paper becomes quite warm. Even without sandpaper or wood, students can feel the heat when they rub the palms of their hands together very vigorously.

Permit students to feel the heat of the barrel of a cycle pump when it is used to inflate a tyre Point out that this heat does not come from friction, but from the work done in compressing the air.

Discuss with students how some primitive people start fires with an arrangement to rub two pieces of wood together very vigorously. Even sparks produced by striking flint and steel together are examples of heat produced in somewhat the same way.

5(c). ALL SOURCES OF HEAT ARE ALSO SOURCES OF ENERGY

Adults readily realize that heat is closely related to energy. In this sub-concept the intent is not simply to tell this to students, but rather to lead them to develop this idea for themselves. They have enough general information about energy to know what an energy source is. Here are some activities which can help them discover that heat sources are also energy sources.

Discussion	**Do sources of heat have anything to do with energy?**

Review with children the common sources of heat they have been recently discussing. These will include the sun, fires (and the fuels which burn) other forms of chemical energy, including food, nuclear reactors, electricity, and many examples of motion, including friction. Lead the students to realize that each of these is a source of energy. Help them to see that the fact that all *sources of heat* are themselves sources of energy suggests that *heat itself* might also be a form of energy. This is true. Remind students that they or their parents usually have to pay for that which they want, as in paying for fuel, for food, and for electricity. (Sunshine is still free.) Remind them also that people usually must purchase energy directly or indirectly, (petrol, support for animals, railway tickets, etc.). Help them see that this too suggests that heat might be a form of energy.

For Better Understanding

The above activities are not intended as *proof* that heat is a form of energy. Such evidence as this has been available for many hundreds of years. Yet two hundred years ago, the leading scientists of the world little suspected that heat was a form of energy. Teachers should be careful that they do not encourage or permit students to jump to a hasty conclusion. It is quite enough that they recognize for themselves the mere *possibility* that heat is a form of energy. In the sub-concept which follows, more and better attention will be given to the development of this important idea.

5(d). HEAT ENERGY CAN BE CONVERTED FROM ENERGY OF MOTION

It is interesting and important to know that heat can be obtained from certain kinds of movement. When two surfaces move over one another, the resulting friction produces heat. This is a clear case of producing heat from movement. Other such examples have already been considered in the preceding sub-concepts. This strongly suggests some relationship between heat and movement. Here are some activities which can help students see the possible relationship between movement and heat, and thus learn more about the nature of heat.

Investigation | **Can motion be converted to heat?**

Materials required
nail
hammer
strip of brass
rubber band

Here are three ways to produce heat from movement. Permit a small group of students to pursue each of the three methods, and let them compare their results.

Place a nail on a rock and pound it vigorously several times. The nail becomes hot. Stretch a rubber band suddenly while it is in contact with the lips. Heat can be felt immediately after the stretching. Bend a strip of metal back and forth several times, quickly. The place where the bending occurs becomes warm. Help the students realize that the heat seems to come from some kind of motion. This suggests that heat may be a form of motion.

Discuss with students how meteors get white-hot from friction when they enter the outer atmosphere. Artificial satellites re-entering the atmosphere must be designed to withstand the great heat produced.

5(e). HEAT CAN BE CONVERTED INTO MOTION

Just as heat can be obtained *from* motion (see sub-concept above) so can heat be converted *into* motion. Indeed, this is one of the very common uses to which man puts heat, as in the cases of steam engines, petrol engines, and other engines which use fuel. It is not the purpose of this sub-concept to have children learn the operating details of these heat engines. Rather, it is hoped that students can learn about the general nature of these devices, and can appreciate the relationship between heat and the mechanical energy which engines produce. Here are some activities which can help students better understand heat engines, and also the nature of heat.

Investigation | **What can we learn from a heat 'cannon'?**

Materials required
metal pipe closed at one end
rubber stopper
pliers or tongs
source of heat

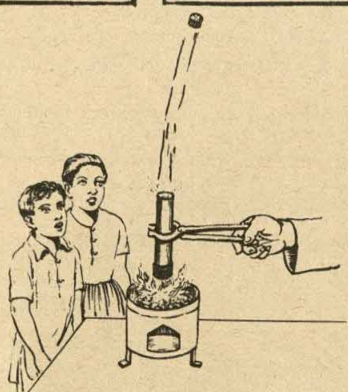


Fig. 4-61
Heat energy increases the pressure inside the pipe; this energy is converted into motion when the cork is forced out

Obtain a piece of metal pipe perhaps 2 cm in diameter and 15-20 cm long. It should be closed at one end, perhaps by welding, or simply by having a metal cap screwed on by a pipe-fitter. Place a few cubic centimetres of water in this and firmly plug the open end with a rubber stopper. Now hold the pipe with tongs or pliers (so as not to get burned) so that the lower end is heated, as shown in Fig. 4-61. After a few minutes, the water inside the pipe boils, steam pressure builds up, and the rubber stopper is blown out of the 'cannon'. Students enjoy seeing this, and also enjoy the suspense waiting for the stopper to be 'fired'. The rubber stopper will not hurt anyone or do any damage when it pops out, although it may fly several metres through the air. This is a clear and exciting example of changing heat (from the flame) to mechanical energy (the motion of the rubber stopper).

Discussion | **What do we know about heat engines?**

Discuss with students the general nature of the heat engines with which they are familiar. Petrol engines and diesel engines are very common on the

highways, while steam engines haul most of the railway trains. Aeroplanes use petrol for fuel if they have propellers, and kerosene if they are jets. Rockets to launch space ships also use fuel, and they provide motion through the medium of heat. Point out to students that these are all examples of using heat to produce motion (mechanical energy). Lead them to the conclusion that this strongly suggests that heat is itself a form of energy—and it might be closely related to movement of some kind.

For Better Understanding

Adults are aware that heat is a form of energy. They also realize at least in a general way, that heat is involved with the motion of molecules. In many older science syllabi, students are simply told this principle, and perhaps also given a few illustrative examples. Here, however, the approach is distinctly different from this older pattern. Here students are given a chance to consider their own experiences, and to make many simple observations. On the basis of these they are helped to develop their own ideas about the nature of heat.

With this as a beginning, they can, over the next few years, develop more and more meaningful ideas of the nature of heat. The teacher should know in what direction the student will be growing, although he should not force students to accept conclusions too soon. The current concept of the nature of heat is that it is related to the motion of molecules. The hotter an object is, the more vigorously the molecules are in motion; hence they have more energy. No wonder there is such a close relation between energy of movement and heat energy. Heat energy can be considered as energy of movement on a molecular scale.

6. THE CONCEPT OF SPEED IS USEFUL TO DESCRIBE THE MOTION OF OBJECTS

Children in class IV have had many contacts with the concept of speed. They speak of one boy being able to run faster than another, and of a man on a bicycle as being able to go faster than anyone can run. An automobile goes even more swiftly, and an airplane faster yet. Rockets go faster than anything man has yet been able to put into motion.

Children who are interested in mechanical things may already have considerable background with facts and figures about speed. They may know that an ordinary automobile can easily go 100 kilometres per hour, but that a passenger jet aeroplane can go nearly 1,000 kilometres per hour. Some children on the other hand have very little background concerning the concept of speed. In this major concept, the plan is to take advantage of what background children may already have, and add to it experiences gained through simple activities. As a result, it is hoped that they can be helped to acquire a meaningful concept of what is meant by the speed of a moving object.

6(a). SPEED CAN BE THOUGHT OF IN TERMS OF 'HOW FAST', 'HOW QUICK', ETC.

When children encounter the concept of speed, they do not always use the same terms, nor do they always use the correct ones. They may use such words as 'speed', 'velocity', 'quick', 'rapid', 'fast', 'in a hurry', and other such common terms. Here are some activities which can help children improve their concept of what speed means and also to use better words to describe speed.

Discussion

How can we describe the rate at which a person or object moves?

Draw children into a discussion of some moving object such as a runner, and an aeroplane, and perhaps a snail. Help them try to compare the way in which these things move. See how many different words they can use to describe the motion. Of course, they will use such words as 'fast' and 'slow'. Try to help them use such phrases as 'the aeroplane moves at high speed'. 'The snail moves at very slow speed'. Help them realize that all their words like 'quick' and 'fast' and 'slowly' are really ways of describing the speed with which things move.

Have a field day to permit races of many kinds. Help the students describe the results using the concept—and the term—'speed'

Encourage children to discuss which animals move the fastest, which ones the slowest. Help them make proper use of the term 'speed' during this discussion.

6(b). AN OBJECT MOVING AT HIGH SPEED GOES A LONG DISTANCE IN A SHORT TIME

The basic idea of the concept of speed is the relationship between distance and time. Something which moves with high speed requires little time to go a given distance. Or in a given interval of time, something moving at high speed can cover a great distance. It is this basic relationship between distance and time which is involved in the concept of speed. Here are some activities which can help students to better understand this fundamental relationship.

Discussion

What means is used by a person who must travel a distance at high speed?

Engage students in a discussion concerning an imaginary trip to some spot they all know—some nearby spot in the community. Ask them how long the trip will take. Their responses will show that they realize this depends on whether one walks or runs, takes a bullock cart, a cycle or an automobile. Even though their responses indicate this, they are not always aware of the relationship they are identifying. Help them phrase their comments in terms such as: "The time required to get there will be less if we go there at higher speed."

Class Activity

Who can go the greatest distance in ten seconds?

Most races are run so as to see who can go a given distance in the shortest time interval. Here is one which is slightly different; here we see who can go the farthest in a given interval of time. Select a place where children can run or cycle in a straight line for a hundred metres or so. Explain that the teacher will start a group off together, and then see who has gone the farthest in an interval of about ten seconds. Let some students compete on a cycle if they wish. Discuss the results with the students. They know 'by instinct' that the person who goes the farthest in that time interval is the fastest—that is, he has the highest speed! Help them discuss this relationship in such terms as: 'A person running at high speed can go a greater distance in a given interval of time'.

Ask children what means of transportation they would use to get to some distant city in the least time. Ask them to defend their choice. Help them phrase their response in terms of the speed of the transportation.

6(c). THE SPEED OF AN OBJECT IS DESCRIBED IN TERMS OF HOW FAR IT GOES IN A GIVEN PERIOD OF TIME

In the foregoing sub-concept, students have been helped to see clearly that a thing moving at high speed covers a given distance

in a brief time interval. They have also seen that a thing moving at high speed can go farther in a given time interval. That is, they have become quite familiar with the fact that speed is related both to distance and to time. Now they are ready to have a first look at a more precise meaning of speed—distance travelled in a unit of time. Here are some activities which can help students become familiar with this accurate and meaningful concept of speed.

Investigation | **What is the speed of our running?**

Materials required
tape line or metre scale
watch with second hand

Measure off a distance of 50 metres or 100 metres. Allow students to run this distance, measuring how long it takes. To compute the speed, divide the distance by the number of seconds required. Thus, if the distance is 100 metres, and a student runs this in 20 seconds, his speed is 100 metres per 20 seconds, or 5 metres per second.

Students may be interested in comparing this with other common speeds. A superb track sprinter can run about 10 metres per second. An automobile speeding along a national highway at 90 kilometres per hour (a very dangerous speed!) is going 25 metres per second.

Discuss with children the facts they know about speed. Some may know how fast a jet aeroplane goes, or they may have heard how fast the wind was blowing during a certain storm. Some may have heard how fast sound travels, or what the speed of light is. As they make their contributions, help them realize that each expression of speed is in terms of some distance per unit of time, such as kilometres per hour, or metres per second.

For Better Understanding

More advanced students soon learn that speed has a very brief and exact definition, thus:

"Speed is distance per unit of time".

In this sub-concept, there is no point in having students memorize such a statement, although it is conveniently brief for the teacher to know. It is also unwise to have students do a great deal of computation concerning speed. It is enough if on a few occasions they help calculate the speed (a matter of simple division) when they know

the distance covered in a given period of time. In such cases, however, the numbers involved should be kept simple and the arithmetic easy. It is not the purpose of this sub-concept to provide training in arithmetic skills. Rather, it is to help students get beginning idea of the concept of speed.

Sometimes the term 'velocity' is used instead of 'speed'. Actually, there is a technical difference between these two terms. In general use, however, and for students at class IV level, the two terms are used as though they had the same meaning.

UNIT 4

ENERGY AND WORK

CLASS V

Overview

By the time they have reached class V level, students working through this syllabus have acquired a simple but accurate set of concepts concerning simple physics. They have learned about measurement—what it is and how it is carried out. They have learned of the need for standards of measurement. They have explored these in terms of distance and force, time and temperature. They have extended the concept of distance into two dimensions to learn about the area of the surface and into three dimensions to learn about the volume of a space. They have also seen how these fundamentals of measurement can be combined into new and useful concepts. Thus they have learned about work which is the product of force times distance, and about density which is the relationship between weight and volume. And they have learned about pressure, the relationship between force and area, and about speed, and the relationship between distance and time.

Much of these students' learning in the first four classes has been concerned with energy—in particular, in the form of work. They have learned that many daily tasks are really concerned with doing work—exerting a force through a distance. They also know that the performance of work requires energy from some source, and that there are many sources of energy to do work. In learning about some of the simple machines, these students have learned how man has devised mechanical devices to make the performance of work easier, more effective, safer, and more pleasant.

These students have also learned some very general and very important things about energy. They know that energy can be obtained from many sources, and that it exists in many forms. They are aware that energy can be converted from one form to another. In particular, they have worked with the conversion of heat energy to mechanical energy (work), and the reverse conversion. They already have the foundations for an understanding of the kinetic-molecular theory of heat, and also for comprehending the principle of conservation of energy.

Here in class V these students can carry their understanding of simple physics even farther. In the first major concept they add to their existing concepts about simple machines. In the second they build on what they already know about forces in fluids to develop the general principle of buoyant forces known as Archimedes Principle. In the third major concept they get a new look

at familiar experiences, providing a first approach to the concept of mass.

The last three sub-concepts are concerned with the motion of objects, and the relationships between the mass of an object, its motion, and the forces which produce the motion. Only the beginnings of these concepts are undertaken at this class level. But the beginnings are sound, and provide an excellent groundwork for further learning at later class levels.

A key point about the learnings in this class is the teaching-learning approach that is used. As in the earlier classes, it is an approach based on the first-hand experiences of students. Some of these are experiences they have in daily living—others are simple activities described in this teacher's handbook. On the basis of this evidence, students are helped to develop concepts on their own. Such an approach is far superior to one of mere memorization. Such an approach helps produce meaningful knowledge, a positive student attitude about learning, and a real acquaintance with the way scientists accumulate knowledge based on evidence.

1. SIMPLE MACHINES CAN BE UNDERSTOOD IN TERMS OF ENERGY

Students here in class V already have a considerable background understanding of simple machines. They know that work is force exerted through a distance. They know that simple machines are used by people to help them do work, but that the machines by themselves can do no work. In earlier classes these students have often referred to work as a form of energy, and they know that some energy sources—often human muscle—are needed to operate simple machines.

Here in class V students will have a closer look at the operation of simple machines. This time they will begin to analyse them in terms of their knowledge of energy and work. They will find that these concepts greatly simplify their understanding of simple machines. At the same time, new experience here will add to their understanding of the nature of energy.

1(a). WHEN A FORCE IS EXERTED THROUGH A DISTANCE, THE WORK DONE IS THE PRODUCT OF THE FORCE AND THE DISTANCE

These students already know that work—in the scientific sense—is done by a force acting through a distance. In the most simple of examples, they have computed the work which is done. Thus, they know that when a 5 kilogram object is lifted through a distance of 3 metres, the work done is 15 kilogram-metres. Now this understanding can be reviewed, and more can be added to it. The specific relationship—work is force multiplied by distance—($W = F \times D$) can be stated more specifically. This principle applies to objects being lifted through a vertical distance, as children have already learned. It also applies to any force acting through any distance. The activities suggested here are useful in helping students acquire this deeper understanding of work.

Discussion | **What do we already know about work?**

Engage students in a discussion about what knowledge they already have about work. They should know that work has a special meaning in science—

a force exerted through a distance. They should know that whenever any force acts through a distance, work has been done. They are most familiar with the simplest case, when an object is lifted by exerting an upward force through a vertical distance. They may be reminded that the amount of work done in such a case is equal to the product of the force (the weight of the object) multiplied by the vertical distance (height) through which the object is lifted.

Demonstration

How can we compute the amount of work done?

Materials required
brick
spring balance
scale
string

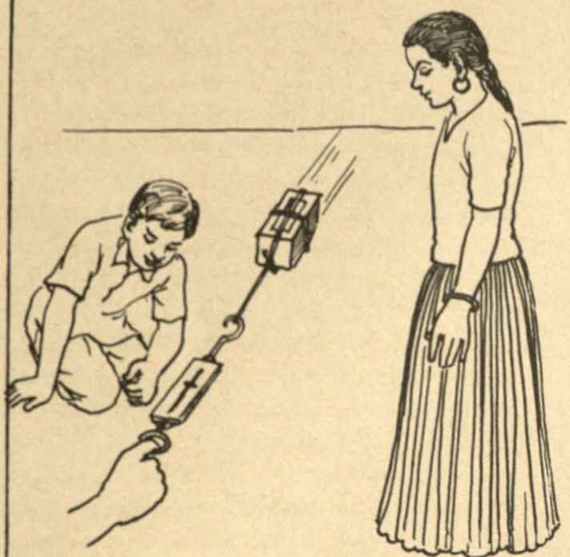


Fig 4-62
The work done in moving this brick is the force applied multiplied by the distance through which the force acts

This is a demonstration of work being done even though no object is being lifted. Use a spring balance and a string to drag a brick across the floor, as in Fig. 4-62. Move the brick slowly and steadily. Have students observe the force required as indicated on the spring balance. Also measure the horizontal distance through which the brick is moved. Remind students that this is not a simple case of lifting the brick through a vertical distance. Weigh the brick and point out that the force required to drag the brick across the floor is not the same as the weight of the brick. Even so, this is a matter of a force acting through a distance. Therefore, it is a matter of work being done. To find out how much work is done, multiply the force times the distance through which it was exerted. For example if the spring balance showed a force of 300 grams and the brick was dragged a distance of 25 centimetres, the work done is the product of these two—300 grams (force) multiplied by 25 centimetres (distance) is 7,500 gram-centimetres.

For Better Understanding

In the example above, the force was measured in grams and the distance in centimetres. Since work is the product of force times distance, the result contains both sets of units. That is why the result is expressed in gram-centimetres. If the force had been larger, it might have been measured in kilograms of force rather than in grams of force. And if the distance had been greater, it might have been expressed in metres instead of centimetres. Then the work done would have been in terms of kilogram-metres rather than in those of gram-centimetres. In any event, the expression for work must include both the unit of force and the unit of distance—regardless of what the units happen to be.

Teachers and students must be completely clear about *what* force and *what* distance are involved in the computation of work. The force is the actual force exerted. When an object is lifted this force is equal to the weight of the object. In other cases, this is not so. In the activity above, the force is not the weight of the object, but is caused by the force of friction between the brick and the floor. The distance involved in the calculation is the distance *through which the force was exerted.* In this case, the distance was not the length of the brick nor of the string which was tied to it. It was the distance through which the force was exerted—the distance through which the brick was dragged along the floor.

When students become older, they will learn a simple mathematical formula for work. It is: $W = F \times D$. This is really a brief and precise mathematical 'sentence'. Translated into ordinary language, this formula means what students already know, that the amount of work done in a given situation is equal to the product of the force multiplied by the distance. The briefness and the directness of the mathematical formula might have appeal for some students. However, it is not necessary to teach the formula to those who prefer to express the concept in the language of words rather than in the language of mathematics. Regardless of which form is used, the meaning is that work is equal to the product of the force *actually applied,* multiplied by the distance *through which it is actually exerted.*

1(b). WHEN A SIMPLE MACHINE IS USED, WORK IS DONE AT THE 'INPUT END' OF THE MACHINE

Students have already learned that some energy is required to operate a simple machine. This energy is the form of work—a force exerted on the machine, and resulting in a movement of the machine. The part of the machine where this work is done is called the 'input end' of the machine. Accordingly, the work done on the machine is called work input—often abbreviated W_i (pronounced 'double-yew-sub-eye'). Like any other example of work, this is equal to a force multiplied by a distance. In this case, it is the force applied to the input end of a machine multiplied by the distance through which it operates. This force is often called the force input, and abbreviated F_i (pronounced 'eff-sub-eye'). The distance involved is the distance through which the force input actually moves. This is the distance input, often abbreviated D_i (pronounced 'dee-sub-eye').

Accordingly, the mathematical statement about work input can be written thus:

$$W_i = F_i \times D_i$$

How easily it is expressed in the language of mathematics!

Children can be helped to understand this principle through having first hand experience with the operation of simple machines. Here are some activities which can help them acquire this understanding.

Demonstration

How can we find the work input of an inclined plane?

Materials required
straight smooth board
small cart with wheels
spring balance
metre scale
string

Arrange an inclined plane as suggested in Fig. 4-63. Use a spring balance to haul a small wheeled cart up the incline. Haul the cart up slowly and evenly, and notice the reading of the spring balance while so doing. This is the force input, F_i, of this simple machine used in this way. The distance input, D_i, is the distance through which the force acts in order to raise the cart from the floor level to the top of the incline. This is the length of the board. To find the work input, W_i, multiply F_i by D_i. Be sure to include the units of force and the units of distance in the product. Point out to students that F_i is NOT the weight of the cart.

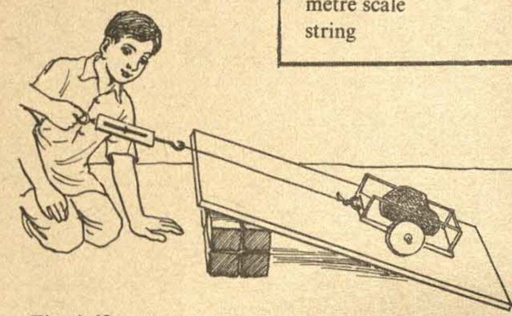


Fig. 4-63
The work input of an inclined plane is the force applied multiplied by the distance through which it acts.

Similarly, D_i is NOT the height of the board. It is the distance through which the force input acts. In this case, it is the length of the inclined plane—the length of the board.

Demonstration

How can we find the work input of a lever?

Materials required
lever bar (stick)
fulcrum for lever
stone to be lifted
spring balance
string
metre scale

Set up a simple lever as shown in Fig. 4-64. In this demonstration the lever will be used to lift a stone. Use the spring balance as shown to support the stone. In this case it is not necessary to *move* the stone. It is sometimes easier simply to support the stone by means of a force measured with the spring balance. This force is the force input, F_i. To measure the distance input, D_i, a specific task must be done.

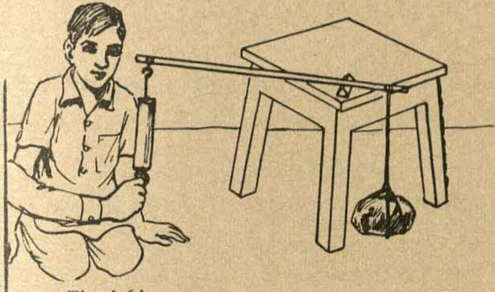


Fig. 4-64
This spring balance shows a force of two hundred grams; when it acts through a distance of twenty centimetres, 4,000 gram-centimetres of work have been done The output force is 800 grams and the output distance is 5 cm.

For example, in the sketch, the lever is used to raise the stone a distance of 5 centimetres. To do this, it is necessary to move the force input through a distance of 20 centimetres. This is D_i. The work input is then the product of F_i (in this case 200 grams of force) and D_i (in this case 20 centimetres). The product of these is W_i, 200 grams × 20 centimetres is 4,000 gram-centimetres. Notice how the units of force and those of distance are both present in the expression for work input.

Emphasize to students that the force input is NOT the weight of the stone being lifted. Likewise, the distance input is NOT the size of the stone, nor the height of the fulcrum. Students are often tempted to think it is the length of the lever. This also is NOT true. The distance input is the distance through which the input force is exerted in order to accomplish a given task.

Discuss the input work of other simple machines with which students are familiar. These may include a wedge or a screw-jack or a windlass. Help them to identify the force input and the distance input. If possible, measure F_i and D_i and use them to compute W_i.

1(c). WHEN A SIMPLE MACHINE IS USED, IT DOES WORK AT THE 'OUTPUT END' OF THE MACHINE

These students know that machines are used to help do work. In the previous sub-concept they have learned specific things about the work input of a machine. Of course, the machine also *does some useful work*, or else the machine would not have been set up and used in the first place. The useful work *done by a machine* may be that of lifting a load, or overcoming friction, or stretching a spring, or running tools or refrigerators. Whatever it is, it is abbreviated W_0 (pronounced 'double-yew-sub-oh'). Like other examples of work, it is the product of a force and a distance. This force, the force output of the machine, is the force actually exerted by the machine as it does useful work. This is often abbreviated F_0 (pronounced 'eff-sub-oh'). In doing useful work, the machine exerts the force output through a distance. This is called distance output, often abbreviated D_0 (pronounced 'dee-sub-oh').

The force output and the distance output are not difficult to find in a simple machine. They are found in connection with the

useful work which the machine does. Here are some activities which can help students understand better the precise nature of the work output of a simple machine.

Demonstration

How can we find the work output of an inclined plane?

Materials required
straight smooth board
small cart with wheels
spring balance
metre scale
string

This activity is very much like that associated with Fig. 4-63. Here, however, attention is focused not on the work input to the machine, but on the work output from it. Use the spring balance to haul the wheeled cart up the inclined plane as in the earlier demonstration. Haul it all the way from bottom to top. Ask children what useful work has been done. Help them realize that the 'job' which has been done is to raise the cart and its contents from the level of the table to the level of the top of the incline. Help them realize that this is the same job that would have been done if someone had simply lifted the cart upwards through the vertical distance shown in the sketch. The force output is then equal to the weight of the cart and its contents. The distance output is the vertical distance from the level of the bottom of the incline to the level of the top of the incline. Thus the work output is equal to the work accomplished if there had been no inclined plane. Students already know how to compute the work involved. It is simply force time distance. In this case, it can be stated more specifically:

$$W_0 = F_0 \times D_0$$

Investigation

How can we compare work input with work output?

Materials required
straight smooth board
small cart with wheels
spring balance
metre scale
string

(This investigation follows naturally upon the one immediately preceding. This one, however, is a quantitative experiment to measure work input and work output and compare the two. This will be of particular interest to the better students. In some cases it can be a teacher demonstration.)

Set up the equipment as in Fig. 4-63. Make measurements of the force

required to haul the cart steadily up the incline. This is F_i. The length of the inclined plane is D_i. The product of these, $F_i \times D_i = W_i$, the work input to the simple machine. The work output can be measured as shown. F_o is simply the weight of the cart and its load. D_o is the height of the top of the inclined plane above its bottom. The product of these two, $F_o \times D_o = W_o$, is the work output of the simple machine.

How do work input and work output compare? We already know that they should be equal. But there is friction involved in hauling the cart up the incline, while there is virtually none involved in lifting the load straight up as in the illustration. Therefore, we might expect that W_i is somewhat larger than W_o. If measurements are made very carefully, this actually is seen to be the case. However, it is difficult to make accurate measurements with simple equipment like this, and experimental results are often quite different from what we might expect. Teachers should avoid the temptation to 'adjust' the readings to make them come out 'as they should'. Rather, it is better to remind students that quantitative investigations with simple equipment are often short of ideal. It is better to treat the data honestly and recognize their shortcomings than to 'cheat' and make the observations come out more desirably.

Demonstration

How can we find the work output of a lever?

Materials required
lever bar (stick)
fulcrum for lever
stone to be lifted
spring balance
string
metre scale

This demonstration is similar to that discussed in connection with Fig. 4-64. Here, however, attention is focused not on the work input, but on the work output. Set up the lever as in the illustration. Discuss with the class what is really being accomplished here. Help them realize that useful work is done as the force input moves through a distance of 20 centimetres. But what is the useful work done? It is the lifting of a weight of 800 grams through a vertical distance of 5 centimetres. Notice that this work output is a specific task—the raising of a certain weight through a certain distance. To raise the weight, the machine must produce a force output F_0 of 800 grams. This force must act through a distance output, D_0. Accordingly, the work output is the product of the two $W_0 = F_0 \times D_0$.

Help students to become very clear about what force output is. It is NOT the weight of the lever, nor the force the operator exerts upon the lever.

It is the force which the lever exerts at the output. Similarly the output distance is NOT the length of the lever, nor the length of a string which might be tied to it. It is the vertical distance through which the weight is actually raised. As in every other case of computing work, we must multiply the force exerted times the distance through which the force acts.

Discuss with children the work output of other familiar simple machines. These might include the work done by a wedge, the work done by a screw-jack, or the work done by a windlass. Help them identify F_o and D_o. If possible, measure these quantities and multiply them together to obtain W_o.

1(d). THE WORK OUTPUT OF A MACHINE CAN BE NO GREATER THAN THE WORK INPUT

There are many people who believe that somehow a simple machine is a 'work-saver'. It is true that by using a simple machine, a person can make a difficult job easy, or an impossible job possible. He can make an unpleasant task pleasant, or convert a dangerous operation into a safe one. Yet if work is used in its proper sense—a force acting through a distance—simple machines are not *savers* of work, not are they *sources* of work. All the work they do at the output end is supplied at the input end. Consequantly, the work output can be no greater than the work input. No scientist has even made measurements on any kind of a simple machine which has contradicted this statement. The statement is also a necessary outcome of the principle of conservation of energy.

In actual practice, the work output of a simple machine is never equal to the work input; the output is always less than the input. This is true because the operation of the simple machine involves movement, and movement involves friction. Some work is done in overcoming the forces of friction. In some machines, like levers, the internal friction is very low. In others, like wedges and screws, internal friction is very high. Here are some activities which can help students better understand the relations between work input, work output, and friction in simple machines.

Demonstration

How do the work input and the work output compare in an inclined plane?

Materials required
long straight board
brick
string
spring balance
metre scale
small wheeled cart

Prepare to raise the brick by sliding it up an inclined plane as shown in Fig. 4-65. This is very similar to some activities already carried out in this major concept. Here, however, the emphasis is on comparing work input

and work output. The numbers used here correspond to the illustration. Notice that the inclined plane is 120 centimetres long (D_i), while one end of it is 20 centimetres higher than the other (D_o). The force required to drag the brick up the incline is 500 grams (F_i), and the weight of the brick itself is 1,500 grams (F_o). In presenting this demonstration, plan to have simple numbers for such quantities.

Have the students calculate the work input (W_i) and the work output (W_o). In this illustration, W_i is 500 grams $\times$ 120 centimetres, which is 60,000 gram-centimetres of work. However, W_o is 1,500 grams $\times$ 20 centimetres, or 30,000 gram-centimetres of work. Discuss with children that although less *force* is required with the inclined plane, more *work* is required. In the strict sense of the word, this simple machine is not a *work saver* but a *work loser!* The work output was just half the work input in this example. The other half of the work was consumed in overcoming the friction within the machine (the sliding action between the surface of the plane and the bottom of the brick).

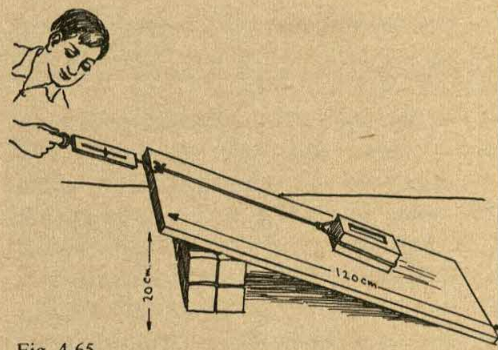


Fig. 4-65
In this example the work input is twice as great as the work output; the difference is wasted in overcoming friction.

Repeat this activity using a small wheeled cart instead of the brick. When work input and work output are calculated, it will be found that a smaller fraction of the work input has been used in overcoming friction. This is true because the friction involved in the rolling cart is less than that of the sliding brick.

For hundreds of years people have been trying to develop 'perpetual motion machines'. These are devices which use systems of levers, flowing water, and gears to do some useful work without having any work put into them. Help the students realize that this is an impossibility, since no simple machine—and no combination of simple machines—can have work output as great as work input. In a 'perpetual motion machine', work input is intended to be zero—so how can there be any work output at all?

1(e). THE PERFORMANCE OF A SIMPLE MACHINE CAN BE EASILY DESCRIBED IN TERMS OF ITS MECHANICAL ADVANTAGE

Most common simple machines have an output force greater than the input force. As a result, the user can exert a reasonable input force to develop a very large output force. In this way, inclined planes, levers, pulley systems, jackscrews, etc. can help workmen overcome very large forces and lift very heavy loads. These might be called 'force multipliers' (but never work multipliers!). The extent to which a simple machine permits a small force input to develop a large force output is a measure of the advantage which the machine gives to the user. This advantage is really the factor by which the force output exceeds the force input. That is, the advantage is the ratio of the force output to the force input. This ratio is called the *mechanical advantage* of the machine. Expressed in the language of mathematics:

$$M.A. = F_0 / F$$

This is the most useful single piece of information about the performance of a simple machine. Here are some activities which can help students understand this simple and important relationship.

Investigation

How can we find the mechanical advantage of an inclined plane?

Materials required
long straight board
brick
string
spring balance
metre scale

Set up an inclined plane as in Fig. 4-65. Make observations of the force input and the force output. In the earlier activity, force input is 500 grams, while force output is 1,500 grams. Whatever the observations may be in the investigation, use them to compute the mechanical advantage. In this example, the M.A. would be F_0 / F_1. This is 1,500 grams of force 500 grams of force, which is 3. Notice that there are no units in the expression for mechanical advantage. This is a simple ratio, a pure number.

Make the inclined plane steeper, or less steep, and repeat the investigation. Note how the M.A. is less when the incline is steeper.

Use other simple machines and measure force input and force output. Use these measurements to compute mechanical advantage. What common machine seems to give the largest M.A.? Which one gives the smallest M.A.? Is the M.A. anywhere less than unity (one)?

1(f). SIMPLE MACHINES ILLUSTRATE THE PRINCIPLE OF CONSERVATION OF ENERGY

Students by now have had many contacts with work, in the scientific sense of the word. They realize that work is done when a force acts through a distance. They have also used the term energy. They know that work is one form of energy. They also know that heat is another form of energy and so is light, electricity and sound. They have learned that energy is the ability to do work.

In dealing with simple machines, students have learned that work output can never exceed (or even equal) work input. They know that a simple machine all by itself cannot do work—it is not a *source* of energy. They are aware that energy cannot simply be made to appear out of nowhere. Wherever there is energy, there is also some source for it. Similarly, energy does not simply 'disappear'.

In view of these understandings about energy which class V students already have, it is very easy for them to accept the principle of conservation of energy. This fundamental principle of physical science is often expressed in this way: "Energy can be neither created nor destroyed, but can be converted from one form to another". It is tempting simply to *tell* this all-important principle to young people. Good teaching, however, calls not for assertion of principles by the teacher, and memorization of them by the students. Rather, it calls for a genuine understanding of what the principle is, and for some understanding of why scientists think the principle is true. Here are some activities which can help students learn a little about the principle of conservation of energy from this educationally sound point of view.

Discussion | **Does energy ever appear or disappear?**

Discuss with children common situations where energy is very evident. These might be in the movement of a truck or bus, in the high speed of a rifle bullet, or of a brick falling from the top of a building. Point out that these are all examples of mechanical energy—or work. Stimulate the students to say from where the energy has come. In the first case it is from the chemical energy of petrol, in the next, from the chemical energy of gunpowder. In the last case, energy was put into the brick—that is, work was done on it—as it was carried to the top of the building. That energy reappears in the fall of the brick from a great height. Help students realize that these are cases of energy being 'saved' or 'conserved'. In none of these cases did energy ever come 'from nowhere'.

Discuss with children where energy goes when work is done in overcoming friction. Does it 'disappear'? No, that energy is converted into heat energy (heat due to friction).

Again discuss the problem of the perpetual motion machine (see page 115. *This time discuss it in terms of the principle of conservation of energy.*

Discuss with students what the source of energy is in a nuclear bomb or in a nuclear reactor. In these cases, some small amount of matter is actually converted to energy. From this point of view, matter might be considered as a highly concentrated form of energy.

For Better Understanding

Children should not be taught the principle of Conservation of Energy as though it were an 'eternal truth', a matter of 'blind faith' on the part of scientists. A brief glance at the development of this principle reveals that this is surely not the case. Indeed, the concept of energy in its modern form was just beginning to develop in Western Europe and England as recently as two centuries ago. The idea of Conservation of Energy is far from an 'article of faith' of scientist. It is a notion which has been developed in view of thousands of measurements made by people in many branches of science for hundreds of years. It is very well illustrated in the case of mechanical energy—work—in simple machines. Suppose a team of expert scientists were to spend twenty years making measurements on all kinds of simple machines. Suppose further, that in all that time they never found one case where energy came from nowhere, or disappeared into nowhere. This might very well lead to the tentative conclusion—a hypothesis—that energy is conserved—that is, it cannot be created or destroyed. In effect, this is what has happened in the history of science. So many careful measurements confirm this hypothesis that it is now accepted as one of the fundamental facts of science. But this principle was developed on the basis of evidence. It was not 'announced' or 'asserted' by some high authority.

This is the nature of principles or 'laws' of science. It is not that science must obey these laws. Rather, the laws and principles must be stated by scientists in such a way that the statements conform to man's observations of the world in which he lives.

2. AN OBJECT IN A FLUID IS SUPPORTED BY FORCE

Any object which is partially or entirely surrounded by a fluid has an upward force (buoyant force) acting on it. For example, if one tries to push an empty bucket into the water, he feels an upward force opposing his push. Objects float because a buoyant

force supports their weight. Children have learned these things in class IV of this unit. Some of them also realize that an object which sinks in water is partially supported by a buoyant force. Objects such as gas balloons which rise in air are supported by the buoyant force of the fluid (in this case air) around them.

Students have already made a beginning at understanding the nature of buoyant force in fluids. Now they are at a stage where they can extend their understanding. When fully extended, this understanding is in the form of an important principle of physical science—Archimedes' Principle. The sub-concepts which follow are arranged to help students grow in this understanding.

2(a). SOME OBJECTS FLOAT ON WATER

Students already know that objects like wood and cork and pieces of wood float on water. They have learned that floating objects are supported by the force (often referred to as the pressure) within the water. They know that an object sinks into the water until the upward force of the water is equal to the weight of the object. Students know that pressure in water increases with depth. That is why an object encounters greater and greater upward force as it is lowered more and more beneath the surface of the water. These students have already been discouraged from thinking that 'light objects float while heavy objects sink'. They have been encouraged to think of floating objects as those whose average density is less than that of water. Here are some activities which can help students review what they already know about floating objects.

Investigation

What determines whether an object will float or sink in water?

Materials required
large pan or bucket
sheet of thin metal such as aluminium foil

Prepare a square of very thin, flexible metal, about 10-15 centimetres on each side. Lower it into the water. Make sure students see for themselves that it sinks. Now challenge students to think of a way that the same sheet of metal can be made to float. Some of them will surely suggest that it be bent into a shape of a boat or a box. Follow up on this suggestion and show that the metal now floats. Point out that the volume of the whole boat or box is much greater than just that of the floating metal. The weight of the two, of course, is the same. Therefore, the average density (weight/volume) is less for the metal boat than it is for the metal sheet. Help students realize that it is not the weight of an object which determines whether or not it will float. This is determined by its average density. The average density of a hollow object is the weight of the object divided by its *total* volume, including all the 'empty space'.

Permit students to push an empty bucket deep into a tub or tank of water. They will observe that the deeper they try to push the bucket, the greater is the upward buoyant force. Remind students that although it is made of iron or brass, the average density of an empty bucket is much less than that of water.

Less than three centuries ago many learned people thought it was impossible to make an iron ship which would float on water. Discuss this opinion with students. Help them understand why this belief is not true.

2(b). OBJECTS WHICH SINK ARE PARTIALLY SUPPORTED BY WATER

Most people know that an object which floats on water is supported by forces within the water. However, many people do not realize that even objects which sink are supported by these fluid forces. The effect of buoyant forces on submerged objects is to reduce their apparent weight. For example, suppose a stone weighs 5 kgf. When submerged in water it has a buoyant force of 2 kgf acting upward on it. It now has an *apparent* weight of 3 kgf.

The source of buoyant force on submerged objects is the same as that on floating objects. In both cases, the buoyant force is due to pressure within the supporting fluid. Here are some activities which can help students understand better the nature and the results of buoyant forces in water.

Investigation

What is the apparent weight of an object immersed in water?

Materials required
brick
string
large jar or bucket
spring balance

Use a spring balance to weigh a brick. Make a record of this weight. Now lower the brick into water as in Fig. 4-66. Notice that the brick is entirely submerged but is not touching the sides or the bottom of the vessel. Again observe and record the reading of the spring balance. Point out the difference between the two weights. How much is the buoyant force of the water on the brick? (the difference between the two weights).

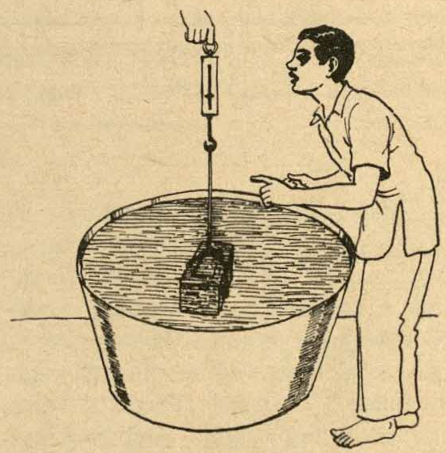


Fig. 4-66
When an object is submerged in water, it appears to weigh less

Ask children to predict what would happen if the brick were weighed with only half of its volume submerged in water. (The buoyant force and hence the reduction in apparent weight would be half such as before.)

Ask children to recall what it feels like to handle heavy stones which are submerged in water Help them realize that it is the buoyant force of the water which makes the stones feel lighter.

2(c). AN OBJECT IN WATER IS BUOYED UP (SUPPORTED) BY A FORCE EQUAL TO THE WEIGHT OF THE WATER DISPLACED

It is not difficult to see how the pressure within the water provides a buoyant force on objects in the water. It can be shown mathematically that the total buoyant force must be equal to the weight of the water displaced by the object. This mathematical proof is beyond the level of class V students. It is relatively simple, however, to demonstrate experimentally that this is indeed the case. Activities such as those which follow will help students to understand the relationship between buoyant force and the weight of water displaced.

Demonstration

How much water is displaced by a floating object?

Materials required
can with notch in the edge
a block of wood
string
spring balance
small tin can

In this demonstration an attempt will be made to weigh the amount of water displaced by a floating object. To do this, a container with a notch in the edge must be prepared. This should be filled and allowed to overflow through the notch. Now weigh a block of wood and record the weight. Carefully lower the wood into the overflow can. Collect all the water which overflows in another small container. Weigh this container with its water, and subtract the weight of the empty container to find the actual weight of water which overflows. The weight of overflow water will be approximately equal to the weight of the block of wood in air. See Fig. 4-67.

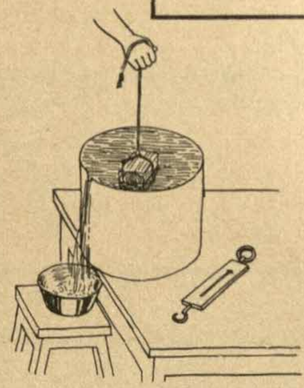


Fig. 4-67
A floating object is buoyed up by a force equal to the weight of the liquid displaced.

Discuss with children such questions as:

What is the apparent weight of the floating block of wood? (Zero.)

What is the buoyant force on the floating block of wood? (Equal to the weight of the wood, so as to make the apparent weight of the wood zero.)

How does the weight of water displaced compare with the buoyant force on the floating wood? (They are equal.) What would happen if the block of wood were pushed deeper in the water, and then released? (More water would be displaced; the weight of displaced water would increase as the buoyant force increases. When the block is released it moves upward because the buoyant force upward on it is greater than the downward force due to its weight.)

Demonstration

How is the buoyant force on a submerged object related to the weight of water displaced?

Materials required
water container with notch in the edge
stone
string
spring balance
small metal can

The demonstration is related to the earlier one in that it attempts to weigh the water displaced by an object. Here, however, the object is one which does not float. Begin the demonstration as before. Fill the can completely full and allow it to overflow through the notch. Weigh the stone and record its weight in air. Lower the stone into the can of water and carefully collect the water which overflows in a small container, as in Fig. 4-68. Weigh the small container of overflow water; subtract the weight of the empty container to find the weight of overflow water. Observe the apparent weight of the stone in water. Subtract this from the stone's weight in air to find the upward buoyant force on the submerged stone. This should be quite close to the weight of the water displaced.

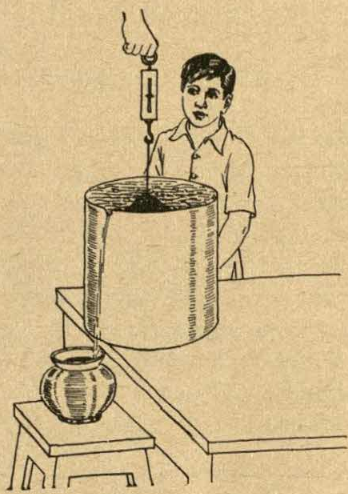


Fig 4-68
An object immersed in liquid is buoyed up by a force equal to the weight of the liquid displaced.

Make clear to students that one or two demonstrations like this do not prove Archimedes Principle. Rather, activities such as those above illustrate the principle and make it more clear.

Ocean vessels have their size indicated in terms of their displacement. Discuss with children what would be the actual weight of a vessel whose displacement is 10,000 *tonnes (its weight equals its displacement).*

Ocean water, with its salt, has a higher density than fresh water. Discuss with children what happens to a vessel which sails from the fresh water of a river into the ocean. (It still displaces its own weight of water; however, it does not have to sink so deeply into the dense ocean water to displace that weight. As a result, the ship rises a little bit in the water when it enters the ocean.)

2(d). ARCHIMEDES' PRINCIPLE APPLIES TO ALL FLUIDS

The sub-concepts above have led to the conclusion that the buoyant force on any object in water is equal to the weight of the water displaced. This applies both to objects which float and to objects which sink. This important principle was discovered by Archimedes of Syracuse (in Greece) about 2,200 years ago. Accordingly, this is known as Archimedes' Principle.

Archimedes' Principle applies not only to water but to all other liquids. It also applies to all gases, including air. That is, the principle applies to all fluids (a fluid is any liquid or gas). A brief and accurate statement of Archimedes' Principle is:

"Any object submerged in any fluid is buoyed up by a force equal to the fluid displaced."

Here are some activities which can help students understand how Archimedes' Principle applies in a variety of situations.

Investigation

Do objects which float in water also float in other liquids?

Materials required
small bucket
oil or petrol
small objects

Select an object which floats in water with only a small part above the surface. Such an object has a density slightly less than that of water. It might for example be 0·9 gram per cubic centimetre. (Water has a density of 1.0 gram per cubic centimetre.) Now try to float the same object in oil or petrol. If the object has been well selected, it will sink. This will be true if the density of the object is more than that of the oil or petrol. Such liquids have a density of 0·7 to 0·9 gram per cubic centimetre.

Discussion

Why do gas balloons stay up in the air?

Discuss with children the well-known situation of a gas balloon which 'seems to weigh less than nothing'. Help them apply Archimedes' Principle to

this situation. For example, a large rubber balloon might weigh $\frac{1}{2}$ gram. Suppose it is filled with a very light gas (hydrogen or helium) which might weigh $1\frac{1}{2}$ grams. This gives a total weight of 2 grams for the balloon and the gas inside it. Such a balloon might be the size of a football. It displaces about 3 grams of air. According to Archimedes' Principle, there is an upward buoyant force of 3 grams on the balloon. But the balloon and its contents weighs only 2 grams. As a result the net upward force on the balloon is 1 gram; therefore, it rises.

Help students realize that the gas balloon does not 'weigh less than nothing'. Rather it weights less than the air which it displaces.

Ask children to think about a kilogram of potatoes which were weighed at the market using a spring balance. How much would they weigh if measured on a spring balance in a vacuum? They would weigh more because there would be no buoyant force of air to help support as there was in the market.

Scientists at Work

Archimedes discovers the principle of buoyancy

Archimedes was a Greek scientist and mathematician who lived more than 2,200 years ago. He made many important contributions to man's knowledge of mathematics and science. Archimedes understood well the principles about levers which you have been studying in this unit. He once said, "Give me a lever long enough and a place to rest it, and I will move the world". He used his knowledge about simple machines and other mechanical devices to help his country. He did this by inventing new and better machines of warfare—machines which would hurl heavy objects and damage ships which were still some distance from the shore.

The ruler of Syracuse, where Archimedes lived, knew of his knowledge and ability. So when he had a problem involving science, he called on Archimedes to help him solve it.

The ruler had been given a fine crown. The giver of the crown had said that this was a crown of pure gold.

However, the ruler had reason to doubt this. So he called upon Archimedes to tell him whether or not the crown was of pure gold. However, he would not permit Archimedes to damage the crown in any way!

Archimedes thought about this problem a great deal. He knew that if the crown were pure gold it would have a higher density than if it were only a part gold. However, he could not calculate the crown's density because he could not calculate its volume.

It was very common in Syracuse for people to spend some time each day relaxing in a large tub of water. While he was bathing, Archimedes noticed that his own arms were buoyed up by the force within the water. As he raised his arm gradually out of the water it displaced less and less water. He noticed that the buoyant force was also less and less. Suddenly he realized the buoyant force of his arm must be equal to the weight of the water displaced.

This at last was the key to his problem! He had a way of determining the volume of the crown without melting it down into a liquid. He could simply lower the crown into water, measure the apparent decrease in weight, and from this know the volume of the crown. Once he knew the volume he could easily calculate the density and thus solve the ruler's problem.

It is said that when Archimedes realized this great triumph in his bath, he forgot completely about his surroundings and went dashing unclothed through the streets of Syracuse shouting "Eureka!", which means "I have found it".

Some of the details of the story may not be completely true. However, it illustrates how a careful observer can find clues to the nature of the universe right in his own familiar surroundings. So many times, as you study science, you find useful ideas in the things you see everyday.

3. THE CONCEPT OF MASS HELPS EXPLAIN MANY THINGS

Class V children are thoroughly familiar with the concept of weight. They know about weighing food, weighing metal, and weighing themselves. They know that weight can be measured with a pan balance or with a spring balance. They have learned that the kilogram and the gram are common modern units of weight.

These young people often use the measurement of weight as a way of determining 'how much' of a material there is. They are confident that under ordinary conditions the weight of a given material or object does not change. If they buy one kilogram of vegetables at the market, they expect to have one kilogram of vegetables when they return home. They may have heard that the weight of an object is *slightly* less on a high mountain than at lower altitudes. Perhaps they have learnt of the situation of 'weight-

lessness' through reading about or listening to stories of space exploration. However, they usually have no personal experience with the fact that the weight of an object can change. The weight of an object, they know, is the attraction between that object and the earth. Young people often feel that this attraction is the same everywhere.

At this class level it is appropriate to introduce another concept relating to the quantity of matter. This is the concept of *mass*. It is a difficult concept to grasp. Children and teachers should be content only to make a beginning at understanding mass at this class level. This beginning will be very helpful to students as they undertake to learn more about mass in future classes. The sub-concepts which follow are arranged so as to be helpful to the students as they make this initial approach to the concept of mass.

3(a). THE MASS OF AN OBJECT IS RELATED TO ITS INERTIA

The concept of mass is even more fundamental than the concept of weight, even though it is less common and less familiar. If students are to learn about the concept of mass, they must learn to think of it almost independently of the concept of weight. They should be helped to wonder how one would measure the quantity of matter in a material or in an object if it were impossible to weigh the object.

One of the fundamental properties of matter is that an object at rest remains at rest unless acted upon by some unbalanced force. This property of matter is often called its *inertia*. That is, the inertia of an object makes it remain motionless unless it is acted upon by an unbalanced force.

Moving objects have inertia too. A moving object remains in motion at a constant speed and in the same direction unless acted upon by an unbalanced force. The amount of inertia which an object possesses depends on the amount of matter that it contains. In this sense one can say that the inertia of an object depends upon the amount of matter in that object. Here are some activities which can help children begin to understand the principle of inertia.

Discussion

What is required to make an object move?

Call students' attention to many common objects which are motionless. These may include objects such as chairs, tables, a jug of water, or a person sitting still. Let children discuss how these motionless objects could be made to move. They would move if they were pushed or pulled; an object on a table will move (it will fall) if the upward force supporting it is removed. A person sitting still moves if he applies an unbalanced force with his muscles. Point out how these objects illustrate the fact that motionless objects can be put in motion only by applying an unbalanced force. In discussing this make frequent and proper use of the word *inertia*.

Demonstration

Can a ball be moved without any force?

Materials required
round smooth ball
smooth flat surface

Place a very smooth ball on a very flat surface. Adjust the position of the surface so that the ball remains stationary. Remind students that such a smooth ball will move very easily on such a smooth surface yet the ball is not moving. Why is this so? Help children realize that the ball is not moving because there is no unbalanced force applied to it.

Discussion

What is needed to change the motion of a moving object?

Call students' attention to common objects which are in motion. These might include a truck speeding along the highway, a ball rolling along a smooth floor, and a rock thrown forcefully through the air. Ask children to say how these moving objects can be stopped, or even slowed down. The truck may be slowed down by the force of friction when the brakes are applied. The rolling ball may be stopped when it hits an obstacle or a person's hand. The rock hurtling through the air may be stopped when it strikes a heavy object. All of these objects if allowed to continue by themselves, will soon slow down due to the opposing force of friction. Help students realize that this is the property of inertia—it makes an object continue in a straight line and at a constant speed unless it is forced to change by some unbalanced force.

Discuss with children the fact that some objects require more force to set them in motion or to have their motion changed than do others. That is, these objects have more inertia.

3(b). THE MASS OF AN OBJECT CAN BE THOUGHT OF AS THE QUANTITY OF MATTER IN AN OBJECT

It has already been noted that the property of inertia of an object is related to the quantity of matter in the object. Children just beginning to learn about this are accustomed to discussing the quantity of matter in an object in terms of its weight. Actually the quantity of matter is given a different name to distinguish it from weight. The quantity expressed by this new term is independent of where in universe the object is. This special

name for the quantity of matter is *mass.* Hence the property of inertia is related to the quantity of matter in an object, which is related to the mass of the object. Here are some activities which can help students become more familiar with the concept of mass.

Discussion

How can we measure the quantity of matter under conditions of 'weightlessness'?

Ask children to imagine themselves in a spaceship in orbit around the earth. Under these conditions they would have the impression of weightlessness. Neither they nor the objects around them would seem to have weight. Under these conditions how could we determine the amount of matter contained in a given object? Certainly the object could not be weighed.

Under conditions of weightlessness it would be possible to determine the quantity of matter—the mass—of an object by applying Newton's first law of motion. Two objects could have their mass compared. All that would be needed is to see which object is the more difficult to put into motion once it is lying motionless. The more difficult it is to put into motion, the more mass it possesses. Help children realize that this is a way of describing the quantity of matter in an object—not by weighing it, but by seeing how difficult it is to change its motion. This would be a matter of determining the inertia of an object. Such a determination could lead directly to the measurement of an object's mass.

Investigation

How can we compare the mass of two stones without weighing them?

Materials required
large rock
small rock
string

Suspend each rock by string a metre or two in length. When the stones are motionless, point out that they will not move unless acted on by some unbalanced force. Point out also that these hanging stones are extremely easy to move because they involve almost no friction. Challenge students to determine which stone is the easier to move.

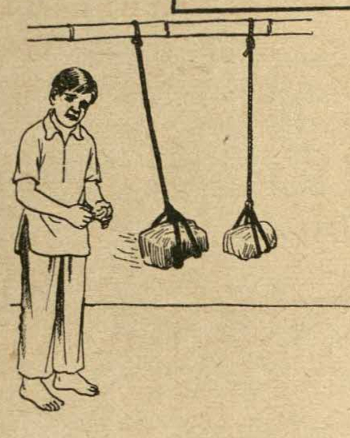


Fig. 4-69
More force is required to move the stone at left; this is because it has more mass than the other stone.

A good way to make this comparison is to invite the student to strike both the large stone and the small one with his fist, as in Fig. 4-69. The pain will easily tell him which stone is the more difficult to put into motion.

For Better Understanding

In the discussion above, the phrase 'unbalanced force' is frequently used. The teacher needs to understand that force may or may not produce a change of motion. A force will not make an object begin to move if there is also an equal force acting on the object, but in the opposite direction. In that case, the two forces balance each other; the net result of balanced forces is zero.

For example, a piece of stone lying on a table does not fall, although a force—the force of gravity—the weight of the object—is acting downward on it. However, the table is pushing upward on the rock with a force equal to the weight of the rock. These two forces are equal, but in opposite directions. They are balanced forces and therefore, produce no change of motion. Only an *unbalanced* force produces a change in motion.

3(c). ALL MASSES ATTRACT EACH OTHER

In the previous sub-concept students have seen that one of the characteristics of mass is that it possesses inertia. There is another important property of mass, too. This property is, that every object attracts every other object with force which is partly determined by the masses of the two objects. Thus, a second property of matter is that it is attracted to every object which has mass. Here are some activities which can help students learn more about the concept of attraction between masses.

Discussion

Do small masses attract each other?

Call students' attention to two common objects in the room—perhaps a chair and a jug of water. Surely each of these objects possesses mass. Is it possible that these objects are attracted toward each other? Ask students to try to measure or find some other evidence for a force of attraction between these objects. Actually the attractive force in this case is so small that it is completely incapable of being measured. Ask students now to think of two larger objects such as the earth and the moon. Some students will already know that the tides of the ocean are produced by the gravitational attraction of the moon. This is a case of two very large objects attracting each other because of the mass which they both contain.

For Better Understanding

The idea that every object in the universe attracts every other object is known as the *Law of Universal Gravitation*. This principle was first pronounced by Isaac Newton. He believed—as we do today—that every object in the universe is attracted to every other

object in the universe. This force of attraction depends on the masses of the objects concerned and also on the distance between them. The farther apart two objects are, the less is their gravitational attraction. That is, two objects must either be extremely large, or they must be very close, in order for the gravitational attraction between them to be measurable.

3(d). THE WEIGHT OF AN OBJECT IS THE FORCE OF ATTRACTION BETWEEN THE OBJECT AND THE EARTH

In the previous sub-concept it was pointed out that every object in the universe is attracted to every other object in the universe. It is the mass of objects which gives them the ability to attract every object in this way.

By far the most familiar example of such attraction between masses is the attraction between familiar objects and the planet Earth. Thus a stone contains mass. The planet Earth contains a great deal of mass. This may be thought of as being concentrated at the centre of the earth. The centre of the earth is about 6,500 kilometres away from a stone at the earth's surface. The mass of the earth, however, is so great that one can feel the force of attraction between the huge earth and the relatively small stone. This force is what is commonly known as weight. Here are some activities designed to help children realize the familiar concept that a weight is really the force of attraction between an object and the earth.

Demonstration

How can weight be thought of as a force of attraction between an object and the earth?

Materials required
tiny round ball
marble
football
very large earthen jug

Place a marble and a football so that they touch each other. Point out that the mass of each object may be thought of as being concentrated at its centre. Ask students what the distance is between the centre of the marble and that of the football. (It is the sum of the radii of the two balls.)

Ask students why one can feel no force of attraction between these balls. (Because each of them has so little mass.) By way of contrast, place the marble next to a large jug full of water. The mass of the jug is much greater than that of the football. Even now no force of attraction between the marble and the jug can be measured.

Help children extend this demonstration in their imagination. Ask them to think of the marble as being next to a ball the size of a room or the size of a mountain. If the marble were next to a ball, 10 kilometres in diameter, it might be barely possible to detect the force of gravitation between the two. However, it would take extremely sensitive measuring equipment. If the larger ball were 1,000 kilometres in diameter, the force of attraction would definitely be noticeable. When the large ball is 13,000 kilometres in diameter, it corresponds to the size of the planet, Earch. Under these conditions

the force of attraction between the marble and the earth sized sphere is a gram or two. We call this attractive force the *weight* of the marble.

3(e). THE WEIGHT OF AN OBJECT MAY CHANGE, BUT ITS MASS REMAINS THE SAME

Under all ordinary conditions, the mass of a given object remains the same no matter where it is in the universe. However, its weight may differ a great deal depending on where it is. As objects go higher and higher above the surface of the earth, the distance between them and the earth's centre increases. As a result, the force of attraction between them decreases. It is for this reason that objects weigh slightly less on mountain tops than they do in the lowlands. However, it requires extremely sensitive measuring equipment to notice this difference. When a balloon rises to a height of 100 kilometres, it actually becomes lighter by about 3% due to its increased distance from the centre of the earth. These are interesting and important cases where the weight of an object changes although its mass remains the same. Here are some activities which can help students realize that although the mass of an object remains the same, its weight can change.

Discussion

What are the conditions of weight on the moon or on planets?

The weight of any object is the attraction between it and the earth. If the object were on some other planet of different mass or of different size, the weight of the object would be different. This would not be because the object has different mass, but because the planet (or satellite) which is near has different mass and different size.

Our satellite, the moon, has a mass less than 1/80 the mass of the earth; however, the radius of the moon is a little more than one-fourth that of the earth. As a result of these two differences, the weight of an object on the moon is about one-sixth of the weight of the same object on the earth. That is, a boy who weighs 60 kilograms on the earth would weigh 10 kilograms on the moon, if weighed with a spring balance. He would feel "lighter on his feet", he could jump higher, and climb a rope more quickly. This is

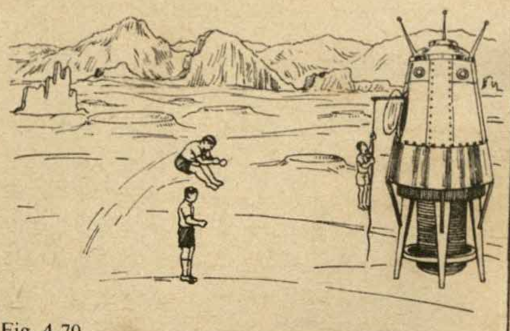


Fig. 4-70
The mass of objects on the moon is the same as anywhere else; however, objects on the moon would weigh about 1/6th as much as on the earth.

true although the mass of the boy remains unchanged. See Fig. 4-70.

Jupiter is a much larger planet than the earth, and it has much more mass. If the same boy could stand on Jupiter's surface, he would weigh 150 kilograms, as shown on a spring balance.

Discuss with children how ordinary objects are so small as compared to the earth that there is usually no measurable force of attraction between two such objects. If two of the largest ocean-going vessels were set side by side and almost touching, the force of attraction between them would only be a few grams.

Discussion

How could we detect the change in the weight of an object?

Challenge children to tell how they could know whether an object has changed weight when carried very high in a balloon. Help them realize that a pan balance would be useless for this purpose. This is true because not only the object in question but also the standard weights used, would change weight with altitude.

However, the change in weight could be observed with a spring balance.

Discussion

How could we determine whether or not mass remains the same, high above the earth?

Remind students that the earth has a radius of 6,500 kilometres. Tell them that in imagination they are going to take a balloon on a trip 6,500 kilometres above the surface of the earth. When they get there, they will be twice as far from the centre of the earth as when they started. Challenge them to say how they will determine what

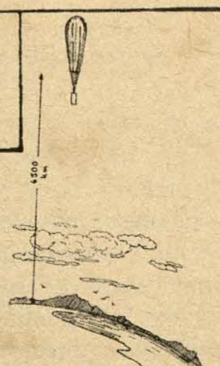


Fig. 4-71

At a height of 6500 kilometres, the balloon is twice as far from the centre of the earth as when it was launched; therefore, objects have one quarter their normal weight.

changes, if any, have occurred in the weight and in the mass of a certain stone carried in the balloon.

Children have already seen (see discussion above) how a spring balance could be used to detect changes in the weight of the stone. If the spring balance were used, the stone which weighed 8 kilograms on the earth would weigh 2 kilograms at this extreme altitude, as in Fig. 4-71.

Our imaginary high altitude scientists could measure the mass of the rock by seeing how much inertia it had. That is, they could measure the force required to set the rock into motion. They would find that the force required is the same at high altitude as it was on the surface of the earth. Evidently the mass remains unchanged.

For Better Understanding

In talking about modern space travel, the term 'weightlessness' is frequently used—and misused. Many people believe that a spaceship in orbit of the earth is beyond the earth's gravity. This is NOT true.

The feeling of weightlessness which astronauts describe is due to the fact that they and their space gravities are constantly 'falling' toward the earth. However, they do not strike the earth, because they are moving so fast in orbit that they literally 'fall *around* the earth'. Most people have occassional brief moments of the feeling of weightlessness. Thus if one jumps from a height of 5 metres, he falls for an interval of about one second. During that brief moment he has a sensation of weightlessness. Suppose he holds a stone in his hand and jumps. Just as he jumps he releases the stone. Naturally the stone falls at the same rate as the jumper itself. Relative to the jumper, the stone does not seem to fall at all! The jumper might well describe the stone as being 'weightless'. Actually of course, both the jumper and the stone have weight. For weight is the force of attraction between them and the earth. If there were no force of attraction, they would not fall!

4. A FORCE CAN CHANGE THE MOTION OF AN OBJECT

When an object is not moving, *i.e.,* when it is at rest, its motion is zero. If an unbalanced force is exerted on the object at rest it sets the object into motion. If unbalanced force continues to be applied in the same direction, its speed increases. On the other hand if the force acting on the object is withdrawn, the object will continue in the same direction at the same speed.

An object in motion comes to rest, *i.e.,* its speed will become zero, if there is an unbalanced force in the opposite direction to motion acting on it. These students have learned that the force of friction always opposes motion. The force of friction, therefore, is the unbalanced force which brings a typical moving object to rest.

Thus an unbalanced force can set a stationary object into motion, can bring a moving object to rest or can increase or decrease the speed of a moving object.

4(a). AN OBJECT AT REST REMAINS AT REST UNLESS ACTED ON BY AN UNBALANCED FORCE

A book lying on the table remains there unless some unbalanced force makes it move. Common objects stay where they are unless somebody moves them. Now suppose that two boys are pushing a table in opposite directions and with the same force. The table will remain at rest. Because the forces acting on it are balanced against each other. Hence, in order to set an object in motion the force must be unbalanced. Simple activities like these can help children understand this.

Investigation | **What is the effect of balanced force?** | *Material required* rope

Obtain a strong rope. Let two children of about equal strength stand opposite each other and hold the rope in both hands. Let the rope be stretched and let them slowly increase the pull as in Fig. 4-72. Let the class watch very carefully. The rope moves slightly in the direction of the boy who applies more force. The other boy then increases his pull to counterbalance it. Then the rope moves in the opposite direction. This shows that the movement occurs when the two forces are unbalanced. Lastly, when one boy relaxes, the rope moves towards the other boy.

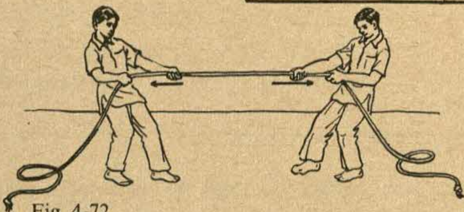


Fig. 4-72
If two forces are equal, but opposite in direction, they are balanced forces; no change in motion results.

Lift a ball and then let it go. The unbalanced force of gravity will set it in motion; that is, the ball falls.

4(b). AN OBJECT IN MOTION REMAINS IN MOTION AT THE SAME SPEED UNLESS ACTED ON BY AN UNBALANCED FORCE

If some one kicks a ball and sets it in motion along the ground its tendency is to remain in motion at the same speed. However, the ball comes to a stop after some time. The force that brings the ball to a stop, making its speed zero, is the force of friction. The ball rolls on the ground which offers the resistance of friction in the opposite direction of motion. In practice the force of friction is never zero. Hence the ball comes to rest after some time. The following activity explains this very clearly.

Investigation	**Why does not a bicycle wheel spin for ever?**	*Material required* cycle

Place a cycle in an inverted position resting on its seat and handle. Spin its rear wheel by rotating the pedals. Let it spin for a while and then apply the brakes. The wheel stops. The friction of the brakes supplies an unbalanced force which stops the wheel. The wheel would have continued to spin if the brakes had not been applied.

Discuss with children the forces which act on a rifle bullet. The force of gravity makes its path curve downward. Except for that, it goes in a straight line. Why does it not continue to move for ever? The force of friction with the air slows it down.

4(c). AN OBJECT IN MOTION CONTINUES ITS MOTION IN THE SAME DIRECTION UNLESS ACTED ON BY AN UNBALANCED FORCE

(i) A CONTINUOUS FORCE IS REQUIRED TO MAKE AN OBJECT CONTINUE MOTION IN A CURVED PATH

Imagine a cyclist riding on a smooth road. He does not have to control its steering in order to keep it in a straight line. When he wants to take a turn round a corner he exerts an unbalanced force through its steering mechanism in order to change its direction. This is true of every motion. Inertia keeps a moving body in a particular direction. It will change its direction only when an unbalanced force acts on it.

There are many examples of motions which follow a curved path, for example, when one rotates a stone tied to a string, the stone moves in a circular path. Now when an object is moving in a circle, it is constantly changing its direction. Otherwise the stone would move in a straight line. The string pulls the stone toward the finger. Thus, as the stone tends to move away from the finger, the pull of the string makes it curve towards the finger. This results in the change in its direction of motion. Continuous pull of the string makes the moving stone change its direction continuously; this results in a circular motion. Carry out the following activities to explain this principle.

Demonstration	**Is a force needed to keep a stone in a circular path?**	*Materials required* stone string

Help a student tie a stone to a piece of string. He can hold the other end in his hand and rotate it as in Fig. 4-73. When it attains some speed, let him

release the string. Let children watch carefully the direction which the stone follows. The pull of the string towards the student's fingers makes the rotating stone change its direction. As soon as this pull is removed the stone travels in a straight line. (This activity should be done outside the classroom, taking care that the stone will not hit anybody.)

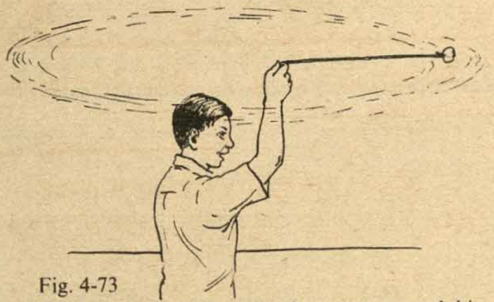


Fig. 4-73
The boy constantly pulls the stone toward his hand; without this force, the stone would go in motion results.

Place a cycle upside-down, rotate its wheel fast and pour water carefully on its tyre. Watch the direction of the movement of water as it flies off the wheel. It continues in a straight line in the direction it was moving when it left the wheel.

(ii) A THROWN BALL FOLLOWS A CURVED PATH BECAUSE THE FORCE OF GRAVITY CONTINUOUSLY ACTS UPON IT

The experience of throwing a stone is very common with children. They have also seen that a thrown stone takes a curved path. Now they have seen that a stone tied to a string and whirling round the finger takes a circular path because the pull of the string constantly changes its direction. A similar thing happens in case of a thrown stone or a ball. The only difference is that instead of the pull of a string, the pull of gravity changes its direction. The following simple activity will illustrate this.

Demonstration	How does the force of gravity affect a rubber ball?	*Material required* rubber ball

Obtain a rubber ball and throw it on the ground in a slanted direction. Let children watch the motion of the ball until it again falls on the floor (draw this curved path on the black-board). When the ball rebounds from the floor, without the force of gravity, it would have taken a straight path. But at every point on its motion the force of gravity pulls it down and makes it change its direction. The

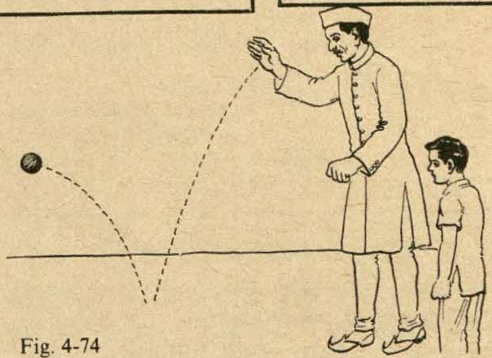


Fig. 4-74
The force of gravity makes the ball travel in a curve; without this force it would go in a straight line.

continuous pull results in continuous change in the direction of the motion. This results in a curved path. See Fig. 4-74.

Let the children trace on paper the paths of stones thrown with different speeds, and at different angles.

(iii) PLANETS AND SATELLITES FOLLOW CURVED PATHS BECAUSE OF THE CONTINUOUS FORCE BETWEEN THEM AND THEIR PARENT BODIES

The earth moves round the sun and the moon moves round the earth. The earth is a planet whose parent body is the sun; while the moon is a satellite whose parent body is the earth. The sun exerts gravitational pull on the earth. The earth without the gravitation pull of the sun would move in a straight line like a ball rolling on a smooth surface. But at every point in the earth's motion, the sun attracts the earth towards it just as a string pulls a whirling stone towards the finger. The earth, therefore, takes a path around the sun. The same thing happens when the moon rotates round the earth. The following simple activity will help explain this better.

Demonstration

What force keeps a planet in its orbit?

Materials required
ball or stone
rubber band

Help a student tie a ball to a rubber band. He can hold the other end in his hand and whirl the ball. The rubber band will stretch. Let him increase the speed of the rotation. The rubber band will stretch to a greater length. Now reduce the whirling motion. The rubber band will contract. The 'planet' moves in closer and follows a smaller orbit. See Fig. 4-75.

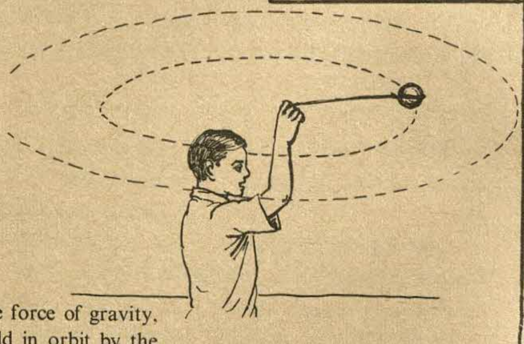


Fig. 4-75
A planet is held in orbit by the force of gravity, much as this rubber ball is held in orbit by the force of the stretched rubber.

Discuss with students why a spaceship does not travel in a straight line once it is beyond the earth's atmosphere (because it is drawn into a curve by the force of the earth's gravity).

4(d). THE ABOVE STATEMENTS CAN BE SUMMARIZED AS THE FIRST LAW OF MOTION

The concepts learned by students so far, if put together, tell about a fundamental rule which describes the movements of all objects in the universe. Whether it is the motion of a little stone thrown by a child or the motion of planets around the sun, both are governed by this fundamental rule which says, "The motion of an object remains constant unless the object is acted upon by an unbalanced force." Objects that are 'at rest' are said to have a zero motion. Thus both the stationary and moving objects are covered by this rule. This rule was developed by Galileo, and later stated very clearly by Isaac Newton. Help children understand this fundamental rule by using the black-board in the following way.

Discussion | **What is the first law of motion?**

Write the First Law of Motion on the black-board. Relate the sub-concepts previously learned to this rule. Let children name the motions of certain objects which they have learned or experienced so far. Explain how every motion named by the student is governed by this fundamental rule.

Discuss how constant motion may be zero motion. Point out also how constancy of movement means both constant speed and constant direction.

Encourage students to read about Newton.

5. THE MASS OF AN OBJECT DETERMINES HOW MUCH CHANGE A FORCE CAN PRODUCE IN THE OBJECT'S MOTION

In the previous major concept of this unit students have had a new look at what a force is. Instead of describing it as merely a 'push' or a 'pull', they have described it in terms of what it can do. A force can change the motion of an object. The development of that major concept was an inductive approach to science teaching. Students began with simple observations and generalized on them to make a statement of a general relation between force and motion.

But the magnitude of a force is not the only factor which determines how great the change in motion will be. The other consideration is 'how big' the object is. Students may associate 'how big' with its physical dimensions, its volume, or its weight. Scientists think of this as the 'quantity of matter'

which the object contains—its *mass*.

From experience, children know that with a given force they can make a greater change of motion on a 'light' or 'small' object (one of little mass) than they can on a 'heavy' or 'large' object (one of great mass). Activities in this major concept will help the students get specific first-hand evidence about the relation between mass and change of motion. From these pieces of first-hand evidence, they can be helped to make a more general statement, just as was done in the previous major concept.

5(a). THE HEAVIER AN OBJECT IS, THE MORE IS THE FORCE REQUIRED TO PUT IT IN MOTION OR TO CHANGE ITS MOTION

More force is needed to move a heavy table than to move a pencil. Similarly one needs more force to stop a heavy roller in motion than to stop a rolling ball. In each case what one really does is to change the motion of an object. Force is required to produce this change in motion. The property of an object which requires force to change the object's motion is called *inertia*. Heavier objects have more inertia than lighter objects. The following experiment will clearly show this to the class:

Investigation

Are heavy objects harder to move than light ones?

Materials required
two stones
rubber bands

Obtain two pieces of stones of different weights. Attach an end of a rubber band to one and try to pull it. Observe the length of the stretched rubber band. Do the same with the other stone. The heavier stone will cause the rubber band to stretch more because more force of inertia must be overcome. See Fig. 4-76.

Obtain an iron ball and a wooden ball of about the same size. Roll the iron ball on the table and ask a child to stop it. Now roll the wooden ball on the table and ask him to stop it. As the iron ball is heavier, it requires more force to stop it.

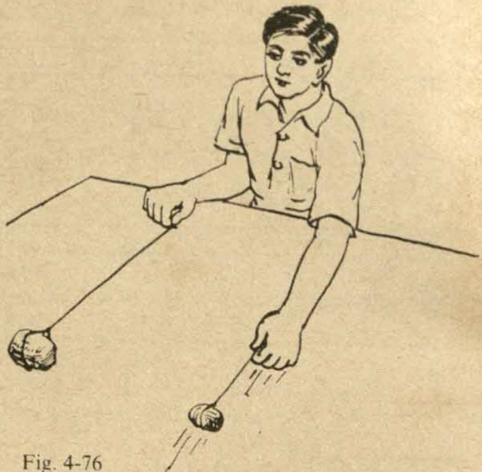


Fig. 4-76
We can easily see that more force is required to move heavier objects.

5(b). THE INERTIA OF AN OBJECT DEPENDS NOT ON ITS WEIGHT, BUT ON ITS MASS

This is a most difficult concept. The teacher may feel gratified if a few of the better students are able to get the idea. Even for those students who do not get the idea, the introduction of this concept at the class V level will make the understanding easier for them when they grow older.

The activities above have clearly shown that the force required to change the motion of an object is greater when the object is

heavier. Stated another way, a given force will provide less change in motion to a heavy object than to a light one. Actually, it is not the *weight* of the object which controls this relationship, but the *mass* of the object. Here is an activity which at least suggests to children that this is the case.

Investigation

Is it really weight which gives objects inertia?

Materials required
heavy object
strong string

Obtain a heavy round iron rod, one weighing a few kilograms. Or, a round unopened food can will do. Invite students to set it into rolling motion and to stop it, always gauging the amount of force needed to change the motion. In view of the above activities, they may say that the required force is great, because the object is quite *heavy*. Ask them how the required force will change, if at all, if you (the teacher) support the weight, and all they do is move it. Some, fooled by the suggestion that you will support the weight, may think the force required will now be much less. Let them try it. You support the object by holding it on a string while they put it into motion, stop its motion, or in other ways change its motion as in Fig. 4-77. They will agree that the force required is approximately the same, regardless of whether or not you support the weight of the object. Evidently it is not weight which provides inertia.

Fig. 4-77
Even though the weight of an object is supported, force is required to change its motion.

Discussion

Do floating objects possess inertia?

Point out that the weight of a boat is balanced by the water, and that as far as the boatman is concerned, the boat weighs nothing. Ask students whether or not a force is required to change the motion of a boat. They will agree (or it can be checked by trying it) that a force is necessary. From this lead them to understand that it is not, strictly speaking, the *weight* of an object which is responsible for its inertia, but rather is quantity of matter—its *mass*.

Arrange for several children to push a parked car with the brakes released on a smooth, hard level road. Point out that they are overcoming friction and inertia, not weight. *They are not strong enough to* lift *the car.*

For Better Understanding

The teacher should understand—and a few of the better students will realize that these activities are in a small way a 'fraud'. True, the teacher supported the weight of the round heavy object in one case, but before that it was supported by the table. Furthermore, the fact that the table, or the teacher, or the water, or the road supports an object does not mean that it has lost weight.

It would be splendid activity if one could do an experiment with the force required to change the motion of an object at some place where the weight is really different, although the mass remains unchanged. To do this, however, it would be necessary to go far away from the earth, where the distance between an object and the earth's centre is much more than the normal 6,500 km. Or one could go to another planet or to the moon where the earth is not responsible for the force of gravity. Obviously, this can be done only through an 'imaginary experiment'. Suppose a boy pushes on a cycle's pedals with all his muscular force. On earth he is just able to start from rest and after ten seconds reach a speed of 30 km/hr, on a smooth level road. If he went to the moon his mass would remain the same (60 kg including the bicycle) but his weight would be about 1/6 as such, or about 10 kg of force. If he could try his experiment on a smooth moon-road, he would still find that he is able to get to 30 km/hr in 10 seconds. Again, if he went to Jupiter, he would find the force of gravity about $2\frac{1}{2}$ times that on earth, so his weight would be 150 kg of force. But his mass is still 90 kg, and in ten seconds, of strenuous effort he would reach a speed of 30 km/hr.

In these imaginary experiments, students can be helped to get the idea that even though there is no direct evidence—weight may change from place to place but mass remains constant. Furthermore, it is the mass, not the weight of an object, which provides its inertia.

5(c). MORE FORCE IS REQUIRED TO CHANGE THE MOTION OF AN OBJECT QUICKLY THAN TO DO IT SLOWLY

This is again a familiar experience. If a boy wants to go faster on a cycle he exerts force on the pedals. In this case the mass of his body and the mass of his cycle remain unchanged. But in order to change its motion quickly, he must apply even more force. If a player kicks a foot-ball gently it changes its motion slowly, if he gives it a powerful kick it changes its motion quickly. Again when a cyclist wants to stop while going at a high speed, he must exert great force on the brakes. If the cycle is moving slowly only a little force on the brakes is enough. The following simple activities will serve as good illustrations of this principle.

Investigation

Does a quick change of motion need more force than a slow change?

Materials required
stone
rubber band

Attach one end of a rubber band to the stone. Hold the other end in one hand and stretch the stone-end to a certain length and let it go. See how quickly the stone moves. Now stretch it still farther and watch the speed of the stone. Thus in order to make a rapid change in the motion more force is required. This is supplied by stretching of the rubber band. See Fig. 4-78, where this principle is applied to a slingshot.

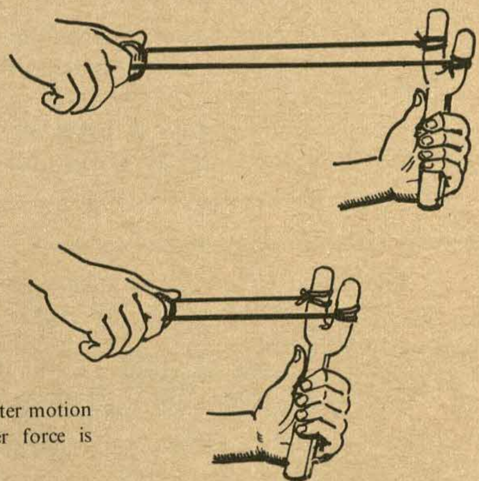


Fig. 4-78
The stone at the top will be set into faster motion than the one below, because greater force is applied to it.

Arrange to have two boys get their cycles going at full speed. Allow one of them 15 *seconds to do it, and the other* 5 *seconds. Which boy must push harder?*

For Better Understanding

Throughout the foregoing sentences, frequent use has been made of such phrases as 'changing motion quickly' or 'a slow change of motion'. More specifically, this is the concept of 'rate of change of motion'. What has been developed here is the idea that the amount of force needed to change the motion of a given object depends on the rate of change of motion involved. The greater the rate of change of motion to be produced, the more force is required.

5(d). THE ABOVE STATEMENTS CAN BE SUMMARIZED BY SAYING: 'THE FORCE REQUIRED TO CHANGE THE MOTION OF AN OBJECT DEPENDS ON THE MASS OF THE OBJECT AND ON THE RATE OF CHANGE OF MOTION'

This is only a restatement of what has been learned from sub-concepts (a), (b) and (c). This is a fundamental rule concerning the effect of force on the motion of an object. This rule was first clearly stated by Newton. It is usually known as 'Newton's Second Law of Motion'. Here are activities to make this more clear.

Discussion

What is meant by Newton's Second Law of Motion?

Write the Second Law of Motion on the black-board. Relate all the previous activities to this rule. In each case bring out clearly the variation in force, in mass and in the rate of change of motion. Review them to establish the relationship between the three. If the students have properly grasped the rule, see whether they can repeat it without rote-learning.

Challenge students to find exceptions to Newton's Second Law of Motion. (They cannot)

Ask students to find out what is meant by the word 'acceleration' (rate of change of motion). Help them restate the second law of motion using the word 'acceleration'.

6. FORCES AND ACTIONS OCCUR IN PAIRS

Students at this class level are by now familiar with many kinds of forces and the ways in which they are commonly used. They know of muscular force and the force due to gravitation; they know of the force which can be exerted by a stretched spring or by a moving object when one tries to slow it down. In many cases, they may have observed that forces occur in pairs. Thus, when they push a table in one direction, they also push on the floor with their feet—and this push is in the opposite direction. When a boatman makes his boat go forward by exerting force on the oars, he also makes the water move backward a small amount.

The above examples provide evidence that forces and actions occur in pairs. There are many instances when the second force or action is difficult to notice. However, it is always there. The sub-concepts which follow and the activities which they include are arranged in the same general manner as in the two preceding major concepts. That is, evidence is supplied to students through first-hand experiences. Then students are helped to use this evidence to develop the scientific principle involved in the major concept.

6(a). WHENEVER A FORCE IS EXERTED IN ONE DIRECTION, THERE IS ALSO AN EQUAL FORCE IN THE OPPOSITE DIRECTION

Children have had many first-hand experiences with forces occurring in pairs. In a tug-of-war, they pull on the rope and the rope pulls on them. When they climb the stairs, they push themselves upward, but

with their feet they also push downward on the steps. What is needed here is close attention to these casual observations. Students need help in studying these common situations, and in generalizing on them to arrive at a sound scientific principle. Here are some activities which can help them do this.

Demonstration

Does an upward jump involve a downward force?

Let a student stand barefoot on another student's hands. Of course, the second student can feel the weight of the first student. Now let the standing student jump nearly straight upward, as in Fig. 4-79. However, he should come down with his feet on the floor. Can the other student feel the additional force on his hands when the boy jumps up. Is it possible for the student to jump upward without exerting a downward force other than that of his own weight? Is this an example of forces occurring in pairs? Are the two forces of the pair opposite in direction?

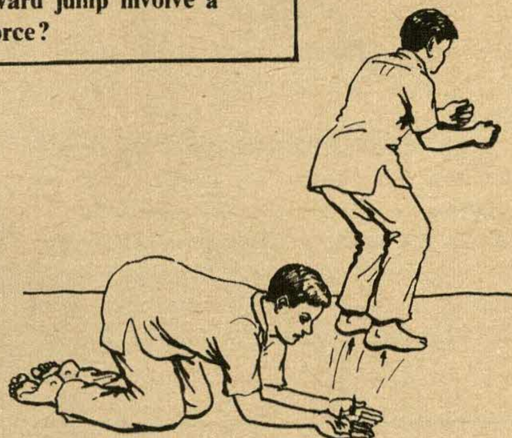


Fig. 4-79
As the jumper's legs push him upwards, they also push downward on the other boy's hands.

Investigation

Can one force be exerted without another opposite force?

Materials required
heavy table
mud
water or oil

Allow a barefoot student to try to push a heavy table across the floor. Make the place where he stands slippery with water or mud or oil. Can he now push the heavy table? Because of the slipperiness, he cannot exert a large backward force. Since forces occur in pairs, he, therefore, cannot exert a large forward force to move the table. See Fig. 4-80.

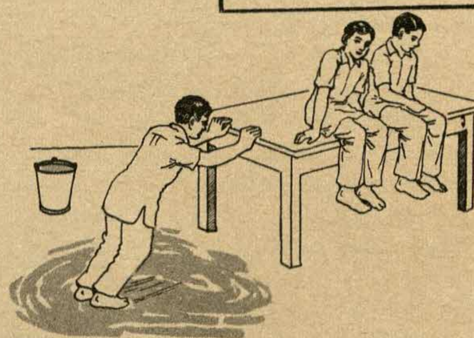


Fig. 4-80
This boy is unable to move the table; the slippery floor prevents him from pushing his feet backward hard enough to move the table forward.

A farmer pulls on his donkey with a rope. The donkey, unwilling to move, pulls on the rope in the opposite direction. Discuss with students how this illustrates forces occurring in pairs.

6(b). WHEN A FORCE SEPARATES TWO OBJECTS WHICH ARE FREE TO MOVE, BOTH OBJECTS MOVE

In the previous sub-concept, it was developed how forces occur in pairs, equal but opposite. If a force is used to separate two objects, and both of them are free to move, the force will make each object move. Students have had many chances to observe this situation. Perhaps they have felt the backward motion they get when they have a heavy rock forward. Perhaps they have heard soldiers or hunters tell how a gun gives a backward "kick" when the bullet is fired forward. Students need help in studying such situations carefully, and in developing a sound scientific principle from such observations. Here are some activities which can help them in this development.

Investigation

Does the act of throwing produce an opposite action?

Materials required
4-wheeled cart
heavy stone

Permit a student to stand in a small four-wheeled cart—one which can move very easily. Now allow him to throw a heavy stone as suggested in Fig. 4-81. Do the boy and the cart move in opposite directions? An even more pronounced effect is seen if the boy himself jumps out of the cart; the cart makes a definite movement in the opposite direction.

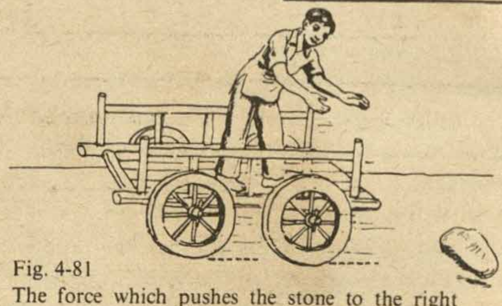


Fig. 4-81
The force which pushes the stone to the right is accompanied by an opposite force which pushes the boy and the cart toward the left.

Investigation

Does a cycle produce any opposite action?

Material required
bicycle

Request a very strong boy to get his cycle moving so quickly that it makes the rear wheel skid. Do this on a road of loose gravel. Carefully observe what happens when the wheel skids. Do the bits of gravel fly backward from under

the rear wheel as in Fig. 4-82. Is this an example of the forward action of the cycle producing an opposite reaction on a part of the road (the loose gravel)?

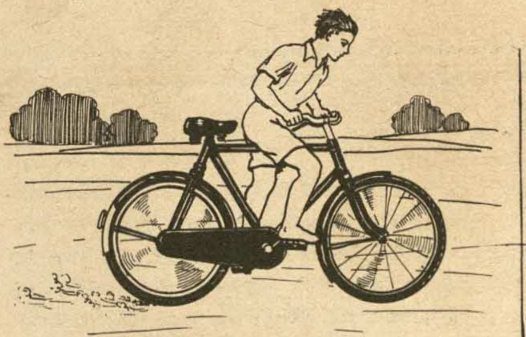


Fig. 4-82
As the cycle moves forward, the rear wheel pushes backward on the road.

Permit two children to stand a half metre apart, facing each other, and ask them to push forcibly on each other's hands. Are there opposite actions as a result?

For Better Understanding

The fact that forces occur in pairs [sub-concept 6(a)] accounts for the fact that motions occur in pairs as in the foregoing activities. Yet there are many common examples where there seems to be only one motion. A car moving along a highway does not make the road move backwards! And a bird flying north does not seem to make the atmosphere move southward. It is NOT true to say that these are not *pairs* of actions simply because of the object on which the force is exerted is too big to move. The principle of 'action in pairs' is true even if one object is the local atmosphere, or the entire highway and the earth to which it is secured. When a locomotive exerts a force on the rails, the train moves forward. Actually, the rails move backward, too, although by an amount far far too small to be observed, even with the most sensitive of instruments.

So the idea of forces occurring in pairs and the idea of actions occurring in pairs are very closely related. Sometimes these are called 'action' and 'reaction' (see also next sub-concept).

6(c). THE ABOVE STATEMENTS CAN BE SUMMARIZED BY SAYING: 'FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION'

The sub-concepts (a) and (b) have already provided an understanding of the above statement. This is a fundamental rule concerning forces and motions. This rule also was first clearly stated by Newton. It is commonly known as Newton's Third Law of Motion or the Law of Action and Reaction.

The activities already performed have made clear the basic principles of this law. Help children to organize in their mind the principles underlying this fundamental rule by doing some black-board work in the following way.

Discussion

What is the meaning of the Third Law of Motion?

Write the Third Law of Motion on the black-board and relate the activities already performed to the principles involved in it. You can help students understand better if you use a little simple arithmetic by assigning some figures to the masses and speeds. For example, when a gun is fired, the bullet (which has little mass) moves very rapidly. But the gun, and the person who shoots, together have very large mass, and therefore move much more slowly. The force on the bullet is the same as the force on the gun and the person who shoots. The fact that they move at different speeds is an illustration of the Second Law of Motion.

Help students recognize action and reaction in common activities such as throwing a ball, or beginning a foot race.

Point out to students that jet aircraft and rockets get their motion from the principle of action and reaction. The jet or rocket motor hurls great quantities of gas backwards at an enormous speed. As a reaction, the engine—and the jet plane or the rocket-craft to which it is attached—moves in the opposite direction.

Scientists at Work

Isaac Newton was one of the world's great scientists

The three laws of motion which have been discussed in the last three major concepts are often called "Newton's Laws of Motion". These are named after Sir Isaac Newton, the man who first stated them in their present clear form. While he drew on the work of other scientists before him, it is his name which is associated with these three very fundamental laws which describe the motions of objects and the forces involved in those motions. Newton also identified the Law of Universal Gravitation [see sub-concept 3(c) of this unit, in this class]. The law of Universal Gravitation is NOT one of the laws of motion.

Isaac Newton was born in a rather

poor farming family in England in 1642. He was raised by his grandparents and had to spend some of his youthful years alone. He was not an extremely healthy boy, and was rather shy. It is possible that these conditions, which combined to make him lonely and by himself, gave him an opportunity to *think* more than some other boys of his age!

As a student in the secondary school and at Cambridge University, young Isaac worked very hard. When he graduated he intended to come back for more study. However, this was 1665—the beginning of the 'Great Plague' in England and Europe. This was a widespread disease which took the lives of many people. The universities closed. So Newton went back once more to the place of his childhood and there he again had time to *think*. It was during this time that Newton made the beginnings of the greatest discoveries of his life. He invented some new forms of mathematics, including the branch known as the calculus. He did much experimenting with light and learned about the nature of colour. While working with light he developed the idea of the reflecting telescope. He formulated the Law of Universal Gravitation from his studies of the moon and its motion. With this principle he showed how the movements of heavenly bodies could be explained in terms of the same forces and laws which describe motions on the surface of the earth. No wonder it is called the Law of Universal Gravitation.

After the plague he obtained a job of teaching mathematics. For many years the shy young mathematics professor was content to teach and give occasional lectures, but otherwise to keep his findings to himself. He had earlier found that whenever he revealed some new discovery, it resulted in a great deal of criticism. However, wise friends finally persuaded him to write down his thoughts about forces and motions and the behaviour of planetary bodies in the sky. So there was published in 1686 one of the most important books of all time, *Philosophia Naturalis Principia Mathematica.* Like the book, the title is in Latin, a language of scholarship in Europe in those days. The title literally means 'Mathematical Principles of Science'. Usually the book today is known by the name 'Principia'. Much of the book is devoted to the precise statements and formulas for the three Laws of Motion and to the Law of Universal Gravitation. These principles are applied to earthly objects, but even more to the motions of objects in the solar system. Indeed, there is nothing about the ordinary motions of planets and satellites and comets and space probes and inter-planetary exploration which is not understandable in terms of the principles of this great book of nearly three centuries ago.

When he was about 50 years old, Newton had a nervous breakdown, and he did little further in the field of science. However, he was a Member of Parliament and Master of the English Mint. He was knighted, and from 1703 until his death in 1727 he was President of the Royal Society, then the most

active and most important scientific society in the world.

Newton, besides being a quiet man, was also humble. He knew that much of what he had discovered and developed would never have been possible were it not for the work of other scientists. He expressed himself on this when he said, "If I have seen further (than others) it is by standing on the shoulders of giants". Newton was also aware that science is a vast intellectual adventure of exploring the unknown. He realized there was much left to learn when he wrote, "Sometimes I feel like a small boy playing on the seashore, finding here and there some bright and shiny pebble, while the great ocean of undiscovered truth stretches out before me."

UNIT 5

MATTER AND MATERIALS

CLASS I

Overview

Children are aware of many objects in their environment. They grow up with some of these objects and develop a sort of personal relationship with them. They use these objects in different ways though they may not be very conscious of it. From observation they know that objects may be made of different materials.

Knowledge from such common experience is, however, not organized by children. In the three major concepts of Unit 5, class I, attempts have been made to organize this experience of children. The first major concept deals with the different types of objects in the environment—the plants, the animals, and things that are neither plants nor animals. In order to acquaint children further with these different types of objects, their uses have been discussed in the second major concept. Objects can be made of a variety of materials that are obtained from different sources. Sources for materials have been discussed in the third major concept of this unit.

There is not much new material to be taught to children in this unit at this class level. They are simply encouraged to observe their surroundings and helped to organize the information thus gathered.

1. THERE ARE DIFFERENT TYPES OF OBJECTS IN THE ENVIRONMENT

A child can name many objects in his environment. From his very birth he starts having experiences with them. The parents, the brothers and sisters, the dolls and the toys are but few examples of the objects he begins to know from the earliest childhood. Even among widely different objects there may be enough similarity to warrant putting them under the same type. An attempt is here made to encourage children to study the familiar objects of their environment.

1(a). THERE ARE MANY VARIETIES OF PLANTS

Young children are familiar with many kinds of plants. They may however be not very conscious of the great variety plants display. Children will also be developing this idea through activities of Unit 8, class I. A start towards this understanding can be made by activities suggested below.

Field Observation | **How much do plants differ in size and shape?**

Invite children on an excursion to a garden or the fields. Help them observe plants of different sizes and shapes. Encourage them to draw diagrams of the most interesting plants.

Supply children some pictures of a few different types of plants. Ask them to paste pictures of similar plants on different pages of a scrap book.

Ask children to name five plants of which the leaves are eaten by human beings (cabbage, mint, lettuce, spinach, parsley, amaranthus).

1(b). THERE ARE MANY VARIETIES OF ANIMALS

Children are familiar with various types of animals. They can easily identify a cat, a cow, a bullock or a buffalo. They may not be able to explain how they identified the animals. The fact that they are able to recognize them shows that children know that animals are of different types. This understanding has further been developed in Unit 9, class I. Activities of the following types may be used to give children a preliminary idea of variety in animals.

Discussion | **How does a cat differ from a mouse or a dog?**

Show children a cat. Ask them how they know that it is a cat and not a mouse or a dog. Help them understand that animals differ in size. A mouse is smaller than a cat; and a dog is usually larger. Encourage children to talk about some other points of difference, *e.g.*, mice squeak, cats mew, and dogs bark.

Let children name two animals that can swim in water, two animals that can fly in air, two animals that ordinarily live on the land and two animals that burrow in earth.

1(c). THERE ARE OTHER OBJECTS WHICH ARE NEITHER PLANTS NOR ANIMALS

Children know that some of the objects around them can neither be called plants nor animals. These are chairs, tables, toys, utensils, cots and so on. Such things do not change position unless one moves them. In this way they differ from most of the animals. Moreover, they differ from most of the plants as they are not usually green. They do not grow, but remain of the same size. Children can develop an understanding about this third group of objects through the following activities.

Discussion

How do a cat, a toy-cat and a cat's picture differ from one another?

Obtain a toy-cat. Do not show it to the children first. Ask them if a cat can walk. Now show them the toy-cat and ask if it can walk. Why is the toy-cat not able to walk? It is not a real cat. It is only a toy resembling a cat in its appearance. Show children a cat's picture. Discuss how it differs from a real cat and a toy-cat.

Invite children to name ten objects from their environment that are neither plants nor animals. Discuss with children the uses of these objects.

2. OBJECTS ARE USEFUL TO MAN IN MANY WAYS

Here children are helped to understand that the familiar objects around them are being put to different types of uses. The children may already know these uses. They can be helped to develop this understanding further in this major concept.

2(a). PLANTS PROVIDE FOOD

This concept is also discussed in detail under Unit 8, class I. Children already know that some articles of their food are provided by plants. This understanding can be developed further through activities such as the following.

Field observation

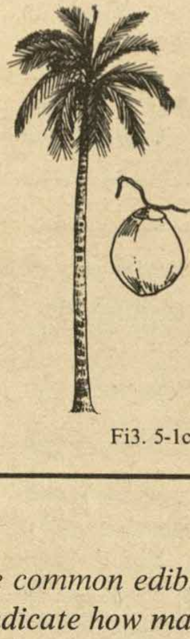
What food materials are obtained from plants?

Take children on a trip to either a vegetable garden or a field with some standing crop. Show them the different vegetables growing in the garden. In a field, let the children see that plants provide cereals and pulses. Invite child-

ren to name some fruits and help them identify some trees or plants giving those fruits, *e.g.*, banana, guava. Draw diagrams of plants and fruits separately on the black-board as shown in Fig. 5-1 and ask children to identify which fruit belongs to what plant. Or, supply pictures of plants and their corresponding fruits to children. Now invite them to paste pictures of the fruit and its plant together on different pages of a scrap book.

Fi3. 5-1a

Fi3. 5-1b



Fi3. 5-1c

Fi3. 5-1d

Fig. 5-1, a-d
Plants provide us with a variety of food materials

Discuss the preparation of some common edibles such as biscuit, sugar, paper, laddu *(sweets) to indicate how materials from plants are used in the preparation of these materials.*

Ask children to name some food materials that are not obtained from plants (milk, egg, meat). Discuss with children how plants play an important role in the quality and supply of even these food articles. For example, the quality of milk and ghee depends partly

on the fodder given to milch animals. Similarly the quality of bird-feed determines the quality of the eggs.

2(b). ANIMALS ARE USEFUL IN MANY WAYS

Children know that animals like cows and buffaloes are very useful because they provide milk. They can name some animals which are used for carrying loads. Children can be helped towards a preliminary understanding of this concept through the following types of activities.

Discussion | **In what ways are animals useful to man?**

Ask children to name three animals that provide milk for human consumption (a cow. a buffalo and a goat). The uses of milk as the principal diet for babies and the sick may be discussed. The uses of milk products may also be taken up in this discussion. Fish, meat and poultry as food materials may also be discussed here. Discuss what animals are used for carrying loads, and what animals are used for keeping a watch over the house.

Ask children to draw the figure of an animal which can be used to carry loads from one place to another.

2(c). OBJECTS OTHER THAN PLANTS AND ANIMALS ARE ALSO USEFUL

Children know that besides plants and animals, there are several other things very useful to them. There are utensils in which food is cooked and served. There are chairs, tables and cots and so on. Such things are neither plants, nor animals; and yet they are very useful. Some activities are suggested here to develop this understanding further.

Discussion | **In what ways do we use things that are neither plants nor animals?**

Encourage children to name ten objects from their surroundings. These should be such that they are neither plants nor animals. Children may be helped to name earthen and metallic things in this connection, *e.g.*, earthenware cups, bricks, *balti,* tumblers, stones, and mortar. Discuss with children the uses of these objects.

Ask children to name five things that interest them. These things should not be plants or animals. Encourage them to suggest why they feel interested in these objects.

3. OBJECTS ARE MADE OF MATERIALS OBTAINED FROM DIFFERENT SOURCES

Objects can often be made of different materials. A chair, for example, may be of wood or of iron, a utensil may be earthen or metallic. It is easy for children to grasp that any object can be made of a variety of materials. A toy may be of wood, plastic or metal. These different materials of which objects are made can be obtained from different sources. The sub-concepts which follow are intended to show that plants, animals, the earth and the sea are big natural sources of materials.

3(a). SOME MATERIALS ARE OBTAINED FROM PLANTS

Children are aware that many plants supply food materials. They know that many household articles are made of wood—material obtained from large plants (trees). Thus many materials of which objects are made are obtained from plants. Children can be helped to have a better understanding of the idea through the following types of activities.

Discussion | **Of what is a cot made?**

Show a cot to the children. Encourage them to find out what different types of materials are used for making it. There are the legs, the two sides and the two ends of the frame, the thick and thin ropes that are woven into the complex web on which one rests. Help them to discover what materials have been used for making these things. All these materials are obtained from plants.

Discuss with children the use of plants for supplying housing materials (thatched roofs), for the preparation of hand-fans (from palm leaves), as firewood and wood charcoal.

Discuss with children about a few colouring materials obtained from plants. During Holi, some coloured water is prepared from

*flowers. Turmeric and saffron are other colouring materials obtained from plants. Leaves of the henna (*mehndi*) plant are also used as a colouring material.*

Invite children to name ten wooden articles in their surroundings.

3(b). SOME MATERIALS ARE OBTAINED FROM ANIMALS

The children know that material obtained from plants can be used to prepare different kinds of objects. This sub-concept helps children in realizing that some objects are made out of the material obtained from animals. This idea can be made clear to children with the help of following types of activities.

Discussion | **What animal gives us wool?** | *Material required* sweater

Show a woollen sweater to the class, and ask of what material it is made. Show them a sheep or its picture. Help them understand that the raw wool from sheep is worked into woollen threads of the sweater.

Discuss with children that one type of silk (natural silk) is obtained from an animal—the silkworm.

Encourage children to find out the names of objects made of animals' skin, e.g., a shoe, a leather belt, or a mashak.

Discussion | **In what ways are animals useful to us?**

Invite children to discuss the use of animals in connection with the materials they supply, under these heads: (a) articles of food from animals (meat, fish, milk, butter, ghee, cheese, eggs, and honey); (b) clothing and garments for animals; (c) decorative and other types of articles from aminals (*e.g.*, buttons and combs from horns, leather goods from animal skin).

Help children to name some materials from animals used for agriculture. (dung for making compost, charas *for lifting water, and bones for fertilizer).*

3(c). SOME MATERIALS ARE OBTAINED FROM THE EARTH OR THE SEA

Many articles of daily use are materials that are obtained from neither plants nor animals. Common salt is one such material. It is obtained either by digging out from the earth or by evaporating sea water. Children can be made aware of these important sources of materials through the following activities.

Field observation

Where do we get the material to make pots?

Invite children to a potter's house while he is preparing the pots. Encourage them to find out what is the raw material used for making pots. Let them ask the potter where he gets the clay. Discuss with children that sometimes pots are made of stone. The earth gives us clay as well as stones.

Arrange visits to a brickfield, a coal depot and a stone-grinder. Explain that earth is the source for all these materials.

Investigation

How do we get common salt from sea water?

Materials required
salt, water, pan

Dissolve enough common salt in water to prepare a strong salt solution. Let a few children taste it. Tell them that sea water tastes likewise because of its dissolved common salt. Put some of this solution for evaporation in a shallow pan—preferably in the sun. Show children the common salt remaining after all the water has evaporated. Let them taste it. Help children understand that common salt is obtained from sea water in almost a similar way. Only instead of shallow pans, large shallow beds are prepared on the ground for evaporating water. Draw Fig. 5-2 on the black-board and discuss with children.

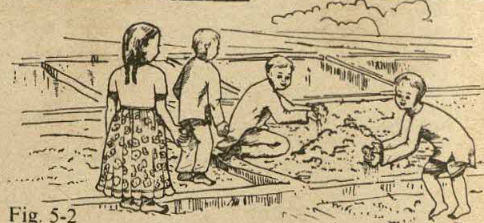


Fig. 5-2
Common salt is obtained by evaporating sea water

Water is essential for human life. Discuss with children the source that supplies them with water (from beneath the earth, the river and the sea).

Scientists at Work

Scientists search in the sea for useful materials

You may not believe that the ocean is a vast treasure-house of materials. Those of you who have visited a seashore will say that a sea is only water with some salt dissolved in it. How difficult it is to believe that there is probably a little of everything in the sea water or that a list of all the materials in sea would fill up a book running into several hundreds of pages. Yet it is true according to scientists. Let us see how scientists study about oceans.

Even primitive man knew that sea water is salty. Probably by accident he discovered that sea water tastes very different from river or spring water; but he never needed to remove salt from sea water. He was happy at his collection of conchs and other shells gathered from the seashore.

As time passed, man learned to obtain salt, pearls and fish from the sea. Till about a hundred years ago, however, there were not many other things obtained from the sea.

How has this knowledge about materials present in sea water increased so enormously during the last hundred years? This is because of the progress made in other fields of science. For example, many inventions have made it possible for man to explore the oceans as he never could before.

Among the many inventions that have made sea diving an interesting adventure is the 'aqua-lung' or breathing apparatus. Formerly it was not possible to go very deep under the sea because the diver needed air to breathe. With an aqua-lung or other such modern invention a man can dive much deeper and stay there longer.

In order to appreciate the importance of sea water as a reservoir of some materials let us imagine a huge box—a cube, one kilometre on each edge. Suppose you filled it with sea water. What would it contain besides plain water? If you could take away all the water there would be some materials left over. To store what is left you would need a godown at least 200 metres high and 200 metres wide and 200 metres long. Most of this would be common salt. There would be many other materials too, even silver and gold. A cubic kilometre of water can provide us 12 metric tons of silver and 6 metric tons of gold. Separation of silver and gold from sea water is a very costly process and nobody, therefore does it at present.

Thus we find that of the materials

present in sea water only some are being extracted at present. Among these are common salt, bromine and magnesium (a light metal used in aeroplanes).

Besides such materials, the sea has always been a rich source for animals like fish and plants like seaweeds. Scientists are exploring the possibilities of cultivating edible sea weeds and farming whales as an answer to the world food problem. Or perhaps seaweed can be used as fertilizer or directly as food for man and other animals.

Even as potential source of fresh water the oceans are very important. Almost three-fourths of our earth is covered by water in the form of oceans. As a medium for sea ships, the importance of sea water is still unchallenged by other kinds of transportation through air or on land. But sea water is too salty to be used for agriculture or drinking. There is however, a possibility that scientists may discover in the near future a very cheap source of power. Then it would be practical to convert sea water into fresh water and irrigate deserts or supply drinking water to cities.

How rich are the ocean waters as a potential source of food, water and other materials!

UNIT 5

MATTER AND MATERIALS

CLASS II

Overview

In class I of Unit 5, children were helped to inquire about the different *types* of objects they come across in their environment. Children's knowledge about familiar objects was thus organized. Here in class II, children will investigate the *variety* in materials of which familiar objects are made.

How does a person distinguish one material from another? Some properties that can form a basis of differentiating materials are discussed in the first major concept of this unit. Breakability, weight, and colour are examples of such properties.

The second major concept deals with two of the three broad classes of materials— solids, liquids, and gases. Liquids do not have a shape of their own; they take the shape of their containers. Solids are rigid. They ordinarily maintain their shapes and, therefore, cannot be poured out. They just fall out of their containers in lumps.

Liquids are not rigid. Hence they are kept in containers. This unit develops the concept of how standard containers can be used for measuring the amount of liquid materials. When the quantity of liquid is measured in a standard container, it is really *compared* with the amount that the container can hold. But a solid object cannot be 'poured'. Therefore, some other method must be used for measuring the space occupied by a solid object. These methods of describing the amount of material in terms of the space they occupy are worked out in major concept 3. They stand in contrast with the methods based on weight— measurement.

In this unit, there is a transition from the everyday world of objects as discussed in class I to a scientist's world of materials. A scientist who works with materials of which things are made is called a *chemist*. He studies the properties of materials in view of the uses to which they can be put. He prepares new materials with new properties to meet new demands.

1. THERE IS A LARGE VARIETY OF MATERIALS; MANY OF THEM HAVE DIFFERENT PROPERTIES

Children are now famliar with at least a few common materials of which household things are made. Even some of the differences among properties of different materials might have been noticed by children. Organization of this common experience of children about

materials is attempted in the sub-concepts which follow.

1(a). SOME MATERIALS BREAK MORE EASILY THAN OTHERS

Earthen or glass pots often break when they fall. This is a common experience which need not be taught to children. However, attention is to be drawn to the fact that breakability is a property of the *material* of which pots are made; and not of the pots themselves. Activities of the following types can help towards development of this understanding in children.

Discussion

Articles made of some materials break when they fall

Ask children what articles they have broken in the past—a tumbler, a mirror, a cup or a pitcher. Write the names of these objects on the blackboard. Ask children to name the materials of which these articles were made. Write the names of these breakable materials beside the names of the broken objects. Invite children to discuss how these objects would not have broken, had they been made of other materials. A tumbler would not have broken, had it been made of brass or copper. Help children to realize that articles break when they are made of breakable materials like glass or clay.

How unpleasant it is that domestic articles like cups and plates often break on falling upon the ground. Discuss with children why these articles are still being made of breakable materials (cheap, hygienic or easy to handle without getting burned).

1(b). MATERIALS DIFFER IN COLOUR AND IN WEIGHT

Besides being more or less breakable, materials may differ in several other respects. They may, for example, have different colours. Some materials may be heavier than others. Children can be encouraged to observe such differences in properties of materials through the following activities.

Investigation

How does comparing weight help in identifying materials?

Materials required
twelve balls of the same size as specified below:
3 of plastic 3 of wood
3 of rubber 3 of clay

Take twelve balls—three each of plastic, rubber, wood, and clay—all of about the same size. Arrange them in

three sets of four different balls each. Wrap the four balls of one set individually with paper so that children do not see the material of these balls. Show the eight unwrapped balls and four wrapped balls to the class. Invite a child to arrange the eight balls into groups of similar weight. Now ask the child to identify the material of the wrapped balls without opening the wrapper. Help him in doing this by comparison of weights as shown in Fig. 5-3.

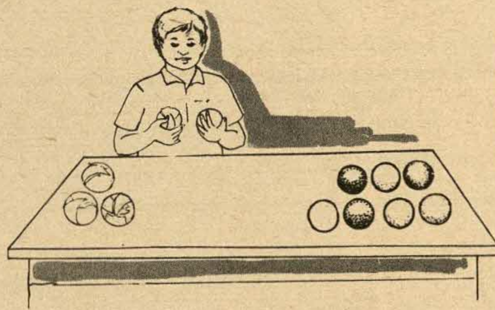


Fig 5-3
Comparing weight helps in identifying materials.

Sometimes it is not necessary to lift an object in order to identify it. One can identify it by the sense of touch. Invite children to name five objects that can be identified in this way. For example, a plastic doll can be distinguished from a cloth doll, and a metal tumbler from a glass tumbler.

1(c). MATERIALS ARE SAID TO BE DIFFERENT WHEN THEY HAVE DIFFERENT PROPERTIES

Children already use this concept when they refer to one liquid as water and the other as milk or oil. They may not, however, be aware of the fact that properties form the basis of this differentiation. Children can be helped in this direction by the following activities.

Investigation

How do properties of materials help us identify objects?

Materials required
paper
cardboard
cloth

Trace the outline of a girl's picture on paper, cardboard and cloth. Cut out the three figures with scissors. Give typical girl's names to these figures made of different materials. Engage children in identifying the figures by their names. Discuss how the identification is based on the nature of material.

Ask children to name five different materials used for making household things. Discuss the differentiating properties of these materials.

2. MOST COMMON MATERIALS ARE SOLIDS OR LIQUIDS

Every day, children take liquid as well as solid food materials. They handle materials like milk and bread. They know that a loaf of bread can be torn apart into two pieces, while a liquid like milk is divided by pouring out. Such common experiences of children are organized here to lead to the understanding that most common materials are either solids or liquids.

2(a). LIQUIDS CAN BE POURED FROM ONE CONTAINER TO ANOTHER

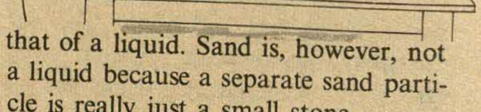
Children will examine liquid materials like water, milk and oil in this sub-concept. The idea is to help them understand that materials, as different as water and oil, have at least one property in common. They both flow and can be poured from one container to another. Activities of the following type will be found helpful for developing this understanding among children.

Investigation | **How do liquids resemble one another?**

Materials required
water
milk
oil
stone
glass tumbler

Show to the class water, milk, oil and a stone kept separately in the four glass tumblers. Invite children to transfer these materials to other tumblers. Discuss the difference they notice in the behaviour of these materials. Help them understand that while a very small amount of water, milk and oil can be transferred, the stone is transferred only as a unit, as shown in Fig. 5-4. Such materials that can be poured out (or transferred in a small fraction) from one vessel to another are called liquids.

Fig. 5-4
Liquids resemble one another in that they can be poured from one vessel to another.



Transfer sand before the class from one container to another. Discuss with children how its behaviour resembles that of a liquid. Sand is, however, not a liquid because a separate sand particle is really just a small stone.

Ask children to name five different liquids. Discuss if these materials can be poured out from one container to another with the same ease. Honey flows out more slowly than water. It is said to be thicker than water.

2(b). SOLID MATERIALS ARE RIGID; THEY CANNOT BE POURED

This sub-concept has been discussed partly in the sub-concept 2(a). Some more activities are suggested here.

Investigation | **In what way are all solids alike?**

Materials required
a few small solid objects

Put on a table objects like a book, a stone, and a shoe. Invite a child to pour some water directly on the table. Water will flow down to the lower side of the table, but a book will not. Help children understand that water has the capacity to flow and, therefore, can be poured from one container to another.

Ask children to take water in one hand and a pencil or a stone in the other. Let them try to close their palms tightly. They will observe that solid materials are rigid and cannot be pressed too tightly. Water is squeezed out of the hand.

Ask children to name five different solid materials used for making domestic things. Discuss with them how these solid materials differ from one another, and how they are alike.

3. THE SPACE (VOLUME) OCCUPIED BY ONE MATERIAL CAN BE COMPARED WITH THE SPACE OCCUPIED BY ANOTHER

Children are now able to differentiate between solid and liquid materials. They can distinguish between an object of one material and a similar object of another material. Even when objects are of the same shape and of the same material, they may differ from one another because they are of different sizes. For example, there are small shoes for children and similarly shaped bigger shoes for adults. The shoe boxes are of different sizes too. Bigger shoes need bigger boxes and smaller shoes, smaller ones. There is more material (leather) in the shoes for adults. Some methods for

comparing the amounts of a material are described in the two sub-concepts which follow.

3(a). THE SPACE OCCUPIED BY A LIQUID MAY BE JUDGED BY POURING IT INTO A CONTAINER

Children are familiar with the idea that the amounts of common materials are often described in terms of their weight. They may also know another way of describing the amount of liquid materials. They have seen milk being measured by using standard containers. A general understanding of this idea can be developed among children through the following activities.

Investigation | **Which of the two liquids occupies more space?**

Materials required
a small measuring vessel
tumblers
milk
water

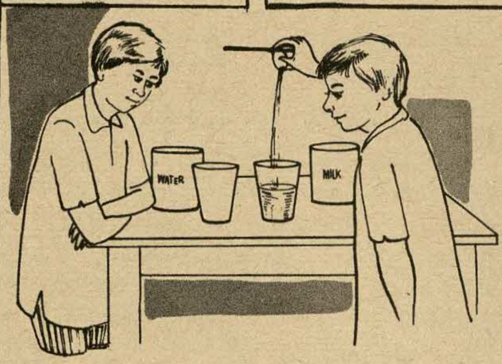


Fig. 5-5
Liquids can be measured by pouring them from a standard container.

Take water and milk in different tumblers. Invite children to find out which of these two liquids occupies more space. Help them to do this with a small vessel. Let them find out how many tumblers of water or milk are required to fill up this container as shown in Fig. 5-5.

Milk and oil are kept in similar glass tumblers. Discuss with children how one can compare the amounts of two liquids by examining them closely.

3(b). THE VOLUME OF A SOLID OBJECT IS THE AMOUNT OF SPACE WHICH IT OCCUPIES

Different amounts (or volumes) of a liquid can be compared and described by using standard containers. Children are interested to know about the method for comparing the different amounts or volumes of solid. Here are some activities that will help them towards this understanding.

Investigation

How can the different amounts of a solid material be compared?

Materials required
2 tumblers
2 saucers
2 iron-pieces
1 small vessel
thread

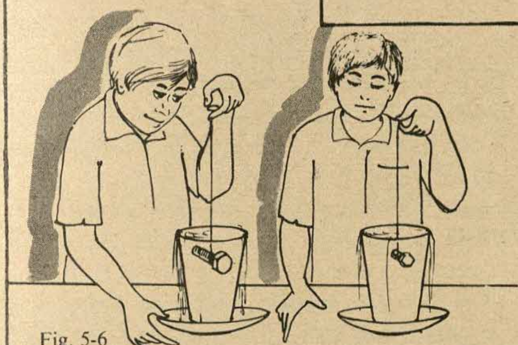


Fig. 5-6
An object put in water displaces a volume of water equal to the volume of the object.

Fill two tumblers with water up to the brim, and set each one on a saucer. Ask children to lower two iron pieces of different size suspended with threads, into the tumblers. Compare the amount of water displaced by the iron pieces, by using some small vessel to collect the water. Help children understand that the bigger piece displaces more water as shown in Fig. 5-6. Throughout this activity use the word 'volume' often and properly.

Discuss with children other ways of comparing the volume of material in solids. Direct observation gives a good guess. Another way is by measuring length, breadth and/or height.

Both solids and liquids have volume; they occupy space. The volume of liquids is measured by filling standard containers. One way of measuring the volume (the space occupied) by a solid is by measuring the volume of liquid which it can displace.

Scientists at Work

Scientists seek new materials

Early man lived in caves. He had tools of stone. With these he could kill animals and fell trees. Tools of stone were not efficient. He was unable to do jobs requiring great precision.

In course of time man discovered other materials to make his tools. He learned to make tools of bronze and iron. He found iron tools to be better than the stone implements in many ways. They were stronger and could be put to a larger number of uses. Discovery of the use of iron as a material for preparing better tools was an outstanding achievement in the history of civilization.

Some discoveries of new materials were quite accidental. Discovery of glass is an example of this type. Glass has been known to man for such a long time that there is no authentic record of the time of its discovery. There is, however, a legend about the discovery of glass more than two thousand years ago.

A ship started from the ancient city of Tyre on the Mediterranean coast. There was a storm and the ship was wrecked. The sailors swam ashore to a beach of fine white sand. There they used dried seaweed and some wreckage to build a fire so that they could cook and keep themselves warm and dry. To their utter surprise, after sometime they saw a little stream of shiny liquid flowing out of their fire. The liquid became hard on cooling. It could be broken. Moreover, one could see through it. It was glass.

During the centuries that followed scientists have been using sand and other materials to prepare different varieties of glass.

You may think the search for new materials is only a story of the past. This is not true. Even today thousands of scientists are engaged in a search for new materials—materials that are better as food, or drink, or for clothings (*e.g.* nylon and terylene) or house-building (*e.g.*, cement-mortar instead of mud-mortar or lime-sand mortar).

How does the necessity for finding a new material arise? Sometimes a better substitute for the old material is required. For example, natural rubber is soft and wears away easily. Scientists solved the problem by devising processes for hardening rubber. Sometimes, people need a new material that is cheaper and more abundantly obtainable than the old one. Plastics is an example. It is very commonly used for preparing different articles. Science has come to our aid in preparing plastics of very different properties.

At times there is need for a new material that has never existed before. You have heard about scientists sending rockets to the moon. Such a task had never been attempted before. Materials with entirely new sets of properties were required for building some components of the rocket. Scientists worked hard to solve this problem as well.

How important is the role of scientists in preparing new materials! Perhaps some of you children will have a part to play in this development when you are older and better educated than you are now.

UNIT 5

MATTER AND MATERIALS

CLASS III

Overview

Materials of which objects are made have been discussed in class II of this unit. However, the discussion was limited to properties of materials and to the idea of volumes of materials. At the class III level, this unit is primarily concerned with investigations about the *changes* undergone by materials. Just as there is a variety in materials, there is also a variety in the changes they undergo.

Change in the physical state—solid, liquid or gas—is one such type of material change. The three different states of matter are investigated in the first major concept. It serves as an introduction to the second major concept which is about interchangeability of the three states of matter. Water, being a very common material, is used as an example to develop the above ideas.

Changes in the physical state are brought about by heating or cooling. These processes can, however, bring about other types of material changes as well. Investigation of these changes enables one to classify them as (i) physical changes and (ii) chemical changes. The above ideas about material changes have been discussed in the third major concept.

Some changes in materials are brought about by keeping them in contact with other materials. Many solids and liquids, and some gases dissolve in water. The fourth major concept of this unit develops understanding about solution and solubility. The effect of temperature on solubility is also discussed in this major concept.

Variety in changes undergone by different materials is a big general area of understanding investigated in this unit. It has also been illustrated how comparison leads to classification.

1. MATERIALS EXIST IN THREE DIFFERENT STATES: SOLID, LIQUID AND GAS

Children have studied in classes I and II that common materials are solids or liquids. They can name a number of liquid and solid materials in their surroundings. In this major concept the children find that some materials are neither solids nor liquids but are gaseous. A material may be solid under one set of conditions, and liquid or a gas under another. Materials are therefore said to exist in three different states: solid, liquid and gaseous. These three states of matter (a general name for all materials) are dis-

cussed in the sub-concepts which follow.

1(a). LIQUIDS CAN BE POURED; THEY TAKE THE SHAPE OF THE CONTAINING VESSEL

Children have learnt that liquids like water and oil can be poured from one container to another. They can observe that liquids take the shape of the containing vessel. A liquid like water does not have a shape of its own. The following activities will be found helpful in developing this understanding.

Investigation

How does water take the shape of the containing vessel?

Materials required
glass vessels of various shapes
potassium permanganate
water

Prepare a coloured solution by dissolving potassium permanganate or ink in a glass of water. Transfer this solution to vessels of different shapes. Help children realize that each time water takes the shape of the containing vessel as shown in Fig. 5-7.

Fig. 5-7
A liquid takes the shape of the vessel which contains it.

Let children carry out this activity with sand. Does sand take the shape of the container? If so, is it a liquid? Discuss with children why sand is not regarded as a liquid. (It consists of visible solid particles.)

The concept that the liquid fills its container evenly can be illustrated through the following activity.

Investigation

Why does water fill its container completely while sand does not?

Materials required
2 tumblers
sand or stone pieces

Ask a child to put some sand or stone pieces into a glass tumbler already full of water. He will observe that some water flows out, as in Fig 5-8. Discuss with the class that water had filled the entire space within the glass tumbler

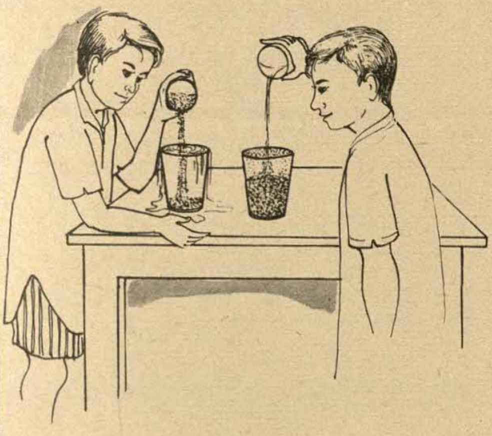


Fig. 5-8
Water appears to fill its container completely, but sand particles leave spaces between them

before the sand was put into it. Water was displaced out of the tumbler because the sand sinking down into the water of the tumbler needed space. Now invite another child to do the above activity in a different way. The glass tumbler is filled completely with sand and some water is carefully added. The children will observe that water goes down the sand. But there is no sand overflowing from the tumbler. This is so because there are spaces between the sand particles.

A heap of sand can be poured while a piece of sandstone cannot. Discuss with children how this may be due to individual particles sticking together in sandstone but held very loosely in sand. Suggest that this may be the reason why solids cannot flow or be poured.

1(b). SOLIDS HAVE DEFINITE SHAPE AND VOLUME

Children are very familiar with the liquid form of water. Some of them know that water sometimes exists as ice also. In contrast with water which takes the shape of the containing vessel, ice has a definite shape. In fact, all solids have a definite shape and definite volume. This understanding can be developed among children through activities of the following types.

Investigation

How does ice differ from water in having a definite shape?

Materials required
2 pieces of ice
vessels

Arrange two pieces of ice of quite different shapes in two tumblers. Ask children to draw quickly the shapes of these ice-pieces as shown in Fig. 5-9. Now wait till ice melts. Discuss with children how the two samples of water from the two different ice-pieces can take any desired shape when they are put into an appropriate container.

Fig. 5-9a

Fig. 5-9b

Fig. 5-9a, b
A piece of ice has a definite shape; when it melts, the resulting water does not have a definite shape.

Encourage children to imagine that solids have lost the ability to maintain a definite shape. What would daily living be like in this case?

Investigation

How does ice resemble water in having a definite volume?

Materials required
4 glass tumblers
ice pieces
4 saucers
measuring cylinder

Fill two glass tumblers to the brim with ice-cold water. Put two saucers below these tumblers to collect displaced water. Take two pieces of ice—one, two or three times as big as the other. Immerse these pieces of ice in glass tumblers. Collect and measure the displaced water. Immediately after cold water has been displaced, take out the ice pieces and put separately in two empty glass containers. Let the ice melt. Measure the volume of water produced. Invite children to

Fig. 5-10a

Fig. 5-10a, b
Ice and water each have a definite volume.

compare (i) the two volumes of displaced cold water and (ii) the two volumes of water produced by melting. They will discover as shown in Fig. 5-10 that one of these volumes corresponding to the bigger piece is two or three times as great as the other volume. Discuss with children how this shows that both solids and liquids have a definite volume.

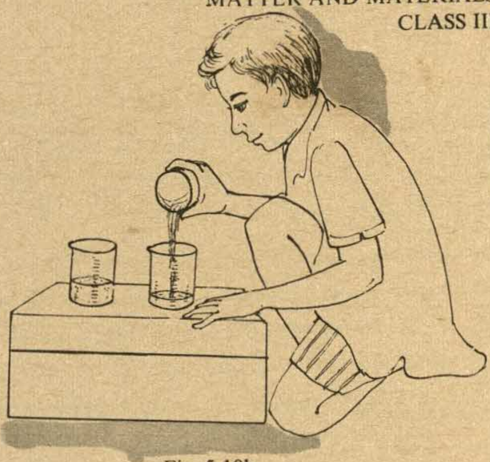


Fig. 5-10b

For selling, milk is measured with standard containers, while ice (or other solids) is weighed. Discuss with children the reason for it. (It is difficult to measure the volume of a solid object.)

1(c). GASES HAVE NEITHER DEFINITE SHAPE NOR DEFINITE VOLUME

The aim of this concept is to make the children understand the tendency of a gas to occupy all the space available in the container. Children can be helped to understand this through the following activities.

Investigation

How does smoke spread through the available space?

Materials required
candle
tumbler
match-box

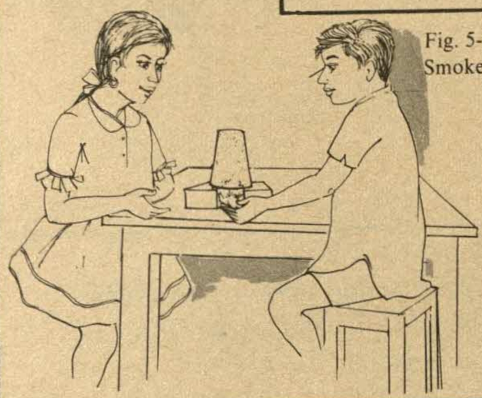


Fig. 5-11
Smoke spreads throughout the available space.

Place a candle on the table. Now lower a glass tumbler over it so as to smother the flame. Help the children to observe how smoke spreads throughout the glass container and assumes its shape. Instead of a candle, an incense stick or smouldering oiled paper or rope can be used, as suggested in Fig. 5-11.

Spill some perfume on paper and blow till the fragrance pervades the room. Discuss how scent vapours now occupy most of the space in the room.

Diseuss the use of a gaseous material based on the fact that gases assume the shape of the containing vessel and occupy its entire internal space as in gas balloons of different shapes. If possible, show to children balloons distorted into different animal shapes, or a cycle tyre may be distorted into the shape of figure 8, *to show that gases have no definite shape.*

Investigation

How does steam differ from water in terms of shape and volume?

Materials required
metallic vessel
spirit lamp
glass tumbler

Boil water in a container covered with a lid. Let the children observe the steam-cloud coming out by lifting the lid upwards. Gently remove the lid and show how the steam-cloud rises upwards from the vessel. Discuss with children that the steam-cloud had been occupying the entire space within it. Invert a vessel over the mouth of the container, so that some steam-cloud enters. Invite the children to observe the inside of this vessel. Discuss why drops of water are visible almost everywhere on the sides of the upper vessel as shown in Fig. 5-12. (The steam occupied the entire container before condensation occurred.)

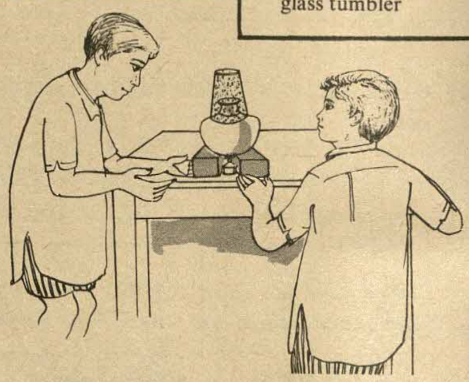


Fig. 5-12
Steam fills all the space available to it.

Put some drops of ghee over a piece of smouldering coal so that flame is not produced. Cover the coal piece with a glass jar. White fumes are seen to fill up the interior of the jar.

1(d). AIR IS MATTER; IT OCCUPIES SPACE AND POSSESSES WEIGHT

Children know that solid and liquid materials occupy space. Air also occupies space and possesses weight. It is as much a kind of matter as are solids and liquids. Here are some activities that will help the children to understand this sub-concept.

Investigation	**Why does a balloon expand when air is blown into it?**	*Material required* balloon

Inflate a balloon. Discuss with children why the balloon expands. The air that is blown in needs space. Balloon walls are stretched; more space is thus provided. If there is a design on the balloon, children can observe the stretching, as in Fig. 5-13. Let them feel the air by pressing the balloon. They will find that air acts like a spring. While deflating, invite children to place their fingers near the opening. They can feel the pressure of the escaping air. Help them realize that such a pressure caused the balloon to expand when air was forced into it.

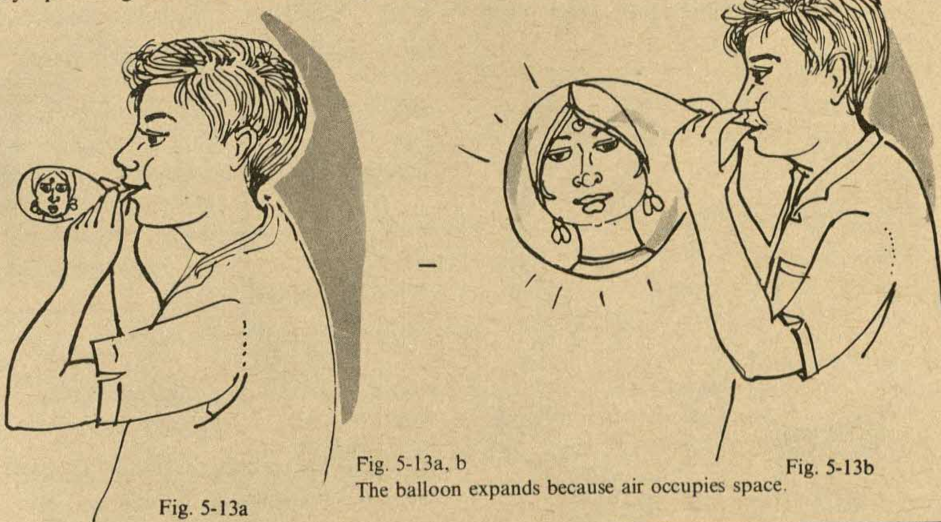


Fig. 5-13a

Fig. 5-13b

Fig. 5-13a, b
The balloon expands because air occupies space.

Put an open bottle upside down into water. Take it out and discuss with children why the inner walls are still dry. Again immerse the bottle upside down and gradually slant it. Children will find that air bubbles escape and allow the water to go in.

Air resembles other materials not only in that it occupies space, but also in that it possesses weight. Children can be helped to understand this idea through the following activities.

Investigation | **Does air have weight?**

Materials required
string
2 balloons
stick

Make an improvised balance with a scale and thread, as shown in Fig. 5-14. Blow up two balloons to about the same size, and tie them with strings to the ends of the scale. Adjust the positions of the balloons to make the stick hang just horizontal. Help children understand that the balloons are full of air and have equal weight. Let the air out of one of the balloons. The children will observe that the empty balloon has deflated (because air goes out) and has risen up. Discuss with children why the deflated balloon weighs less than the inflated one. (It contains no air and is, therefore, lighter.)

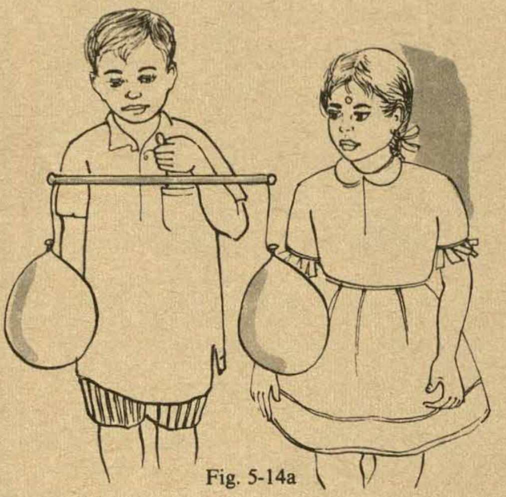


Fig. 5-14a

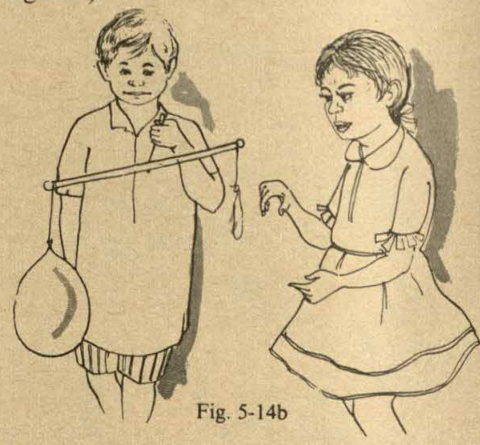


Fig. 5-14b

Fig. 5-14a, b
The inflated balloon weighs more than the empty one; this indicates that air has weight.

Man lives at the bottom of an ocean of air—the atmosphere. Discuss with children why people are not aware of the weight of air above. This is partly because the air pressure is exerted in all directions, and partly because we are accustomed to it.

Different materials are referred to by different names. But all of them, irrespective of the fact whether they are solid, liquid or gas, possess weight and occupy space. Help children understand that matter *is a general name for all types of materials.*

2. THE THREE STATES OF MATTER ARE INTERCHANGEABLE

Children are now aware that materials exist in three different states—solid, liquid, and gaseous. They have observed in the case of water that ice (a solid) can be changed into water (a liquid) and water can be changed into steam (a gas).

Some concepts in Unit 2, class III are also concerned with change of state. Teachers may wish to help students review those concepts now. Here in Unit 5 the treatment goes farther than in Unit 2. The emphasis is now on the energy involved in the changes of state, and on these changes as *physical* (not chemical) changes. The sub-concepts which follow are intended to help children understand how changes of state occur.

2(a). ICE CHANGES INTO WATER AND WATER INTO STEAM BY ADDING SUFFICIENT HEAT ENERGY

Most children have observed ice changing into water and water into steam. They may not realize, however, that addition of heat energy is necessary for these conversions. Children can be helped to grasp this idea through the following activities.

Investigation

How does ice change into water and then into steam?

Materials required
ice
spirit lamp
2 containers

Put the same quantity of ice in two containers. Heat one of them with a spirit lamp flame. Keep the other as it is for comparison. Discuss with children why ice changes into water and water into steam more quickly

Fig. 5-15a

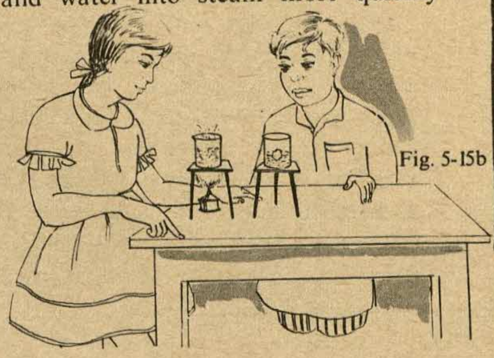


Fig. 5-15b

Fig. 5-15a, b
Ice changes into water, and then into steam, more quickly if it is heated.

in the heated container, as shown in Fig. 5-15. Help them understand that heat is required for the changes: ice to water and water to steam. But ice melts in the other container as well. Discuss with children that the surrounding air and other materials are slowly supplying heat energy in this case.

Discuss with children why ice melts when exposed to air—but paraffin wax does not. Discuss why, when in contact with boiling water, both ice and paraffin wax melt. The boiling point of water is higher than the melting point of paraffin wax. Normal air is not hot enough to melt the paraffin wax. For accomplishing the change from solid to liquid there is always a need for sufficient heat energy.

Discuss the changes in physical states by recalling experiences of hardening and softening of butter, ghee, and vegetable fats in the different seasons.

2(b). COOLING CHANGES STEAM INTO WATER AND WATER INTO ICE: COOLING IS THE LOSING OF HEAT ENERGY

Children are now aware that heat is needed to convert solids into liquids and liquids into gases. The aim of this sub-concept is to make them realize that this process can be reversed. If heat is taken away from steam, it turns into water. If heat is further taken away from water it turns into ice. The following activities will help the children to understand this concept.

Discussion | **How is ice-cream made?**

Arrange a visit to the *kulfi-walla*'s (ice-cream seller's) house when he is preparing *kulfi*. Let children observe how he fills the liquid material (milk, etc.) in the metallic containers and then seals the lid with dough. Discuss that he adds common salt or saltpetre to the ice-pieces to make them still cooler. Discuss why he shakes the big earthen pot, so that the cooling of liquid contents (milk) is more rapid and efficient. Let children observe that the liquid contents in the metal containers have solidified. Discuss why there is so much water in the earthen pot now. (Heat transferred from the milk to the ice.)

Discuss with children why melted paraffin wax solidifies when allowed to set, but water does not change into ice under the same conditions. (Paraffin wax solidifies at room temperature; water solidifies only when it gets much colder.

3. HEATING AND COOLING PRODUCE IMPORTANT CHANGES IN MATERIALS

Children now understand that solids such as ice and paraffin wax turn into liquids if heated. These liquids if cooled will again turn into solids. Melting and boiling are heat-produced changes in matter and they are reversible changes. But not all changes produced by heat are reversible. For example, if sugar is heated it turns black. Cooling does not return it into its original form. In the following sub-concepts, attempts have been made to help children grasp these ideas.

3(a). CHANGE OF STATE IS A PHYSICAL CHANGE

It is now well known to children that some solids turn into liquids, then into gases upon heating. Here they are helped to understand that this is a property common to most solids. Such changes that are reversed by removal of the cause of the change (addition of heat in the above cases) are known as *physical changes*. The understanding about a physical change may be developed among children through the following type of activities.

Discussion | **How is iron formed into different shapes?**

Draw diagrams of iron pots, engine parts, pumps, etc. on the black-board, as shown in Fig. 5-16. Discuss how these articles were prepared from molten iron by casting into different shapes. (The iron may be heated until it can be drawn into the desired shape, as in the case of rods and rails.)

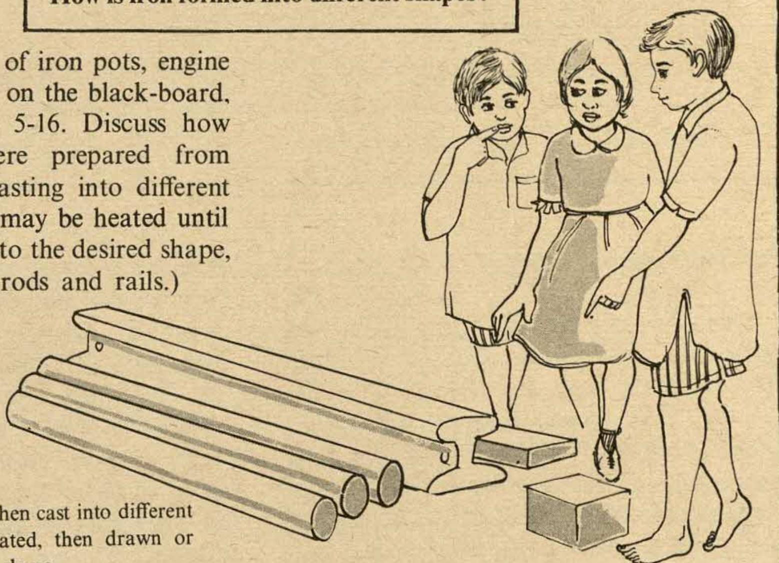


Fig. 5-16
Iron is sometimes melted, then cast into different shapes; or, it may be heated, then drawn or hammered into the desired shape.

nut oil are generally found in a solid state.

3(c). MANY COMMON CHANGES ARE CHEMICAL CHANGES.

Children observe daily in their homes how cooking changes the colour, smell and taste of food materials. Through the following type of activities children can be helped to understand that changes in materials produced during cooking are often irreversible and, therefore, called chemical changes.

Discussion

How does cooking change food materials?

Invite children to describe some changes they have observed during cooking of food materials. Let them describe how milk changes upon prolonged boiling (into *malai* and *khoa*) and how vegetables and pulses change upon cooking. Help children understand that cooling of the cooked food material does not reverse the changes brought about by heating. Such changes in materials are known as chemical changes.

Discuss with children why food materials should be cooked (to make them free from germs, to improve the taste and make them more digestible).

Discuss with children some chemical changes taking place in the kitchen but not related to cooking, e.g., burning of wood, conversion of milk into curd.

For Better Understanding

Heating converts food articles in such a way that they become more easily digestible. Germs are also killed during heating. It is, therefore, more hygienic to eat cooked food. When fresh fruits are to be taken, they should be washed properly.

A chemical change produces a change of the material. Cooked egg is not the same material as is a raw egg. Charcoal left after burning is a different material than the wood that was burnt to get it.

3(d). MOST CHEMICAL CHANGES ARE NOT REVERSED BY COOLING

Food articles once cooked cannot be converted into their original material. Cooling here does not reverse the changes caused by heating. Such a change, in which a new substance is formed, is called a *chemical*

change. Food articles acquire a new set of properties when they are cooked. They are different materials in the chemical sense, than they were. If the cooked materials are cooled, they do not change back to the uncooked form. Activities of the following type can help children understand this idea.

Discussion

What happens when cooked materials are cooled?

Discuss with children what happens when cooked rice, potatoes or pulses are cooled. Do they return to the original state they were in before cooking? Help them understand that cooking produces irreversible changes in materials.

Ask children to name food articles that are baked, boiled, or cooked. Encourage children to describe the changes produced in these food materials by baking, boiling, or cooking. Discuss which of these changes are chemical.

For Better Understanding

In a physical change the material does not change. Only the physical state of the material changes. Or there may be a change in colour, e.g., the glow and colour of an electric bulb filament. These changes are reversible and called physical. In a chemical change, an entirely new material with different properties and different chemical composition is formed.

4. WATER CAN DISSOLVE MANY THINGS

Water is the most abundant liquid on earth. It has, therefore, been chosen as a typical liquid for the study of dissolving characteristics of liquids. The sub-concepts which follow are designed to help students become familiar with water solutions.

4(a). WATER DISSOLVES MANY SOLIDS

Some solids lose their shape and appearance when mixed with water. The solid is then said to have been *dissolved* by water. Activities of the following type will help children in understanding this idea.

Investigation

How do salt and sugar behave in water?

Materials required
glass tumblers
sugar
salt

Put about a spoonful of sugar in a glass container, and a spoonful of salt into another. Add equal amounts

of water to these containers and stir. Ask children to observe and describe what they see. Ask how they can show that salt and sugar are not really gone from water. Tell children that this change is called dissolving. Salt and sugar are said to have been *dissolved* by water.

Children may be encouraged to name (i) four solids that can be dissolved in water (alum, blue vitriol, gum arabic, sal-ammoniac), (ii) two solids that can be dissolved in kerosene (paraffin wax, tar), (iii) four solids that are not soluble in water (stone, glass, wood, iron).

4(b). SOLIDS DIFFER IN THEIR SOLUBILITIES

Children do not know that different solids are soluble to different extents in water. It is easy to grasp the difference between 'soluble' and 'insoluble'. But now students need help to appreciate the difference between 'more soluble' and 'less soluble'. The following activities would be found helpful to develop this understanding among children.

Investigation

Are solids equally soluble in water?

Materials required
glass tumblers
sugar
salt

Repeat the activity described under 4(a). Invite children to note the time required for dissolving a teaspoonful of sugar and salt respectively in the same quantity of water. Sugar and salt should be powdered for this activity. Stirring of water in the two containers should also be done the same number of times. Add small but equal quantity of powdered sugar and salt to their respective containers. Find out in this way whether salt or sugar, dissolves more easily in a given quantity of water. Help children understand that being 'more soluble' means getting dissolved more quickly. Substances are said to be more soluble than others when they can be dissolved to a larger extent in comparable quantities of water.

Encourage children to take five substances and find out if they are (i) insoluble (ii) slightly soluble or (iii) very soluble in water.

4(c). WATER CAN DISSOLVE SOME LIQUIDS AND GASES

Children know that water can dissolve a number of solids. Water can also dissolve some liquids and gases. Activities of the following type would help children in understanding this idea.

Investigation | **Do liquids also dissolve in water?**

Materials required
2 glass tumblers
honey
glycerine

Prepare two glasses of water. Take a little honey (let children recognize it by tasting) and glycerine (let children taste). Ask a child to add drops of honey to water and stir. Honey dissolves. Let another child add glycerine to water. This also dissolves. Help children understand that water can dissolve some liquids, just as it dissolves some solids.

Sometimes when water is kept in glass tumblers, many tiny bubbles are seen on the inner side of the glass. Discuss with children that these are formed by air coming out of the solution. Air bubbles appear on the inner surface of the glass because the solubility of air in water has been reduced due to warming up.

Ask children which of the following liquids can be dissolved in water: milk, sugarcane juice, lemon juice, orange juice, kerosene, glycerine, ground-nut oil, etc. (Water does not dissolve kerosene and ground-nut oil.) Encourage students to experiment with these materials.

Air also dissolves to a small extent in water. Here is an activity which illustrates this fact.

Investigation | **Does water dissolve air?**

Materials required
vessel
water
spirit lamp

Heat water in a container and ask children to observe. They will notice that bubbles are rising up or sticking to

the container walls as in Fig. 5-18. Discuss with children that air is less soluble in hot water than in cold. That is why bubbles are seen coming out.

Fig. 5-18
When water is heated, the air dissolved in it appears as tiny bubbles.

Investigation

What happens to dissolved gas when pressure is released or heat is applied?

Materials required
soda-water bottle
spirit lamp

Show a soda-water bottle to children. Open the stopper before the children. Help children observe that bubbles begin to appear in the clear liquid of the soda-water bottle as soon as the top is removed. Explain to them that the bubbles are of the gas (carbon dioxide) that cannot now remain dissolved because pressure has been released. After some time the contents of the bottle become clear. Now heat the bottle gently. Gas bubbles begin to come out again. Discuss that the solubility of a gas decreases with a decrease in pressure and with an increase in temperature.

For Better Understanding

When sugar is dissolved in water, the product thus obtained is called a *solution*. The liquid in which a substance (solid, liquid, or gas) dissolves is called the *solvent*. The substance that dissolves is called the *solute*. Water is the solvent and sugar is the solute for the above solution.

The extent to which a solute can dissolve in a specified quantity of solvent is limited at any given temperature. It is called *solubility*. The solubilities of solid and liquid solutes in any liquid solvent are generally greater at high temperatures. Gases, on the other hand, dissolve less at high temperatures.

A solute dissolves in a solvent with many of its characteristics unchanged. Sugar is sweet, and so is its solution in water. Moreover, one can get back all the dissolved sugar by evaporating the solution. The change, involved in the formation of such solutions as salt, sugar, alum, or blue vitriol in water is, therefore, a physical change.

Scientists at Work | **The beginnings of modern chemistry**

There are fascinating stories about the search for the 'Elixir of Life' (*amrit* or the drink which would make one immortal) and the 'philosopher's stone' (*paras*—a stone that would convert cheap metals like iron and copper into the precious metal, gold).

You might have heard from your grand-parents the story of getting *amrit* and *visha* from the sea-churning by the Devas and Asuras. This is a tale from mythology. Nevertheless it shows how deep had been the human concern for defying death and poverty. *Amrit* and *paras* were considered to be the means of becoming all-powerful.

Besides mythological tales, there is historical evidence to show how serious man was in his efforts for acquiring immortality and immeasurable wealth. Less than 400 years ago it was easy to find people working in secluded and dark corners for discovering an easy recipe to convert base metals into gold. Such persons were known as *alchemists*.

An alchemist believed in transmutation—conversion of one type of material into another. The origin of this belief may be traced back well more than 2000 years when Greek philosophers saw Egyptian artisans making less precious metals into gold-like imitations. The Egyptian workmen realized that they were making *imitation* jewellery and not really producing pure silver and gold. But the Greek philosophers saw in these observations, support for their ideas about the nature of matter. Aristotle, one of the greatest Greek philosophers, thought that all substances were made of primary matter in the form of four elements—fire, air, earth and water. This organization was achieved by a balancing of the four basic properties of these elements—hotness, dryness, coldness, and moistness.

The Greeks were misled by the blind faith in their theories. This shows the importance of open-mindedness in science. The Greek philosophers had enormous faith in the craftsmanship of Egyptians. They moulded the interpretation of their observations about the preparation of imitation gold, so as to suit their own ideas. This resulted in a blind search for philosopher's stone continuing for many centuries.

Alchemists believed that gold was a noble metal. Iron, copper, etc. were regarded as base metals. It was thought that by purifying iron sufficiently, gold could be prepared. Similarly it was argued that if the human body was purified sufficiently, it would become immortal. This idea developed into a search for the Elixir of Life.

What type of activities were conducted by the alchemist in his dark and lonely laboratory? Mostly he was heating mixtures of different types of materials or preparing solutions. He would also try to cool the products of the reaction.

It is not that man always worked for bringing about a desirable change—iron into gold or a mortal human body

into an immortal one. Sometimes he was interested in stopping a change. Dead bodies decay rapidly. Early Egyptians believed that even after death a person returns to his body. If the body perished, the soul would also perish. They discovered the process of converting dead bodies into 'mummies' and thus preventing the changes involved in the decay of body. Even today we do the same sort of thing—preventing a change—when an iron surface is nickel-plated to check erosion.

It is true that many alchemists devoted much of their time searching for clues to eternal youth and boundless wealth. Often their efforts were encouraged and financed by royalty, who, of course, wanted to benefit from the results of the alchemists' findings. Much time was wasted. Many alchemists were dishonest—they thought they had to be in order to keep the favour and the support of their ruler.

Over a period of a few hundred years, however, the alchemists gathered much valuable information. Some of them were true scientists at heart, with an inquiring mind and great resourcefulness and patience. Gradually the 'magic art' of alchemy developed into the primitive science of chemistry.

About two centuries ago, the alchemists were gone, and chemistry was well on the way to becoming the complex science that it is today. Although the Elixir of Life has not yet been discovered, chemists have achieved much in the form of such invaluable medicines as penicillin and streptomycin. Compared with the past, we are much more successful in the prevention and cure of diseases. And what is more, the future is brighter still.

UNIT 5

MATTER AND MATERIALS

CLASS IV

Overview

Children have learnt about changes in materials in their previous class. Changes involving alteration of the physical state and formation of a solution were discussed there in some detail. But merely observing changes, or even describing and classifying them, does not constitute science. One has to put forward a hypothesis, a good and workable idea to explain why the changes proceed the way they do.

Formulation of one such workable hypothesis about the changes in matter has been attempted in Unit 5 here at class IV level. There are two major concepts in this unit. The first analyses the observation about dissolving. For example, if a solute is found breaking up into tiny invisible particles, it is probably because the solute is composed of such particles. Similarly, if some solids dissolve in liquids without an appreciable increase in volume, it is probably because there are spaces between the particles of the liquid. Particles of the solid solute are accom modated in these spaces. All this leads to a useful hypothesis about the structure of matter.

The second major concept 'All matter is made up of small particles called molecules' describes a hypothesis about the composition of matter based on three assumptions. The first of these proposes that matter is composed of molecules which are so small that they cannot be seen. The second and third assumptions are about spaces among molecules and about the increasing motion of molecules. How these ideas help explain changes in the physical states of matter will be taken up in class V.

The material discussed under this unit is important in that it teaches children how to make a good guess for explaining observations.

1. WHEN A SOLID DISSOLVES IN A LIQUID, IT SPLITS UP INTO TINY PARTICLES WHICH SPREAD THROUGHOUT THE LIQUID

It is known to the children that many solids can dissolve in liquids. But they do not know *how* a solid gets dissolved in a liquid. Some of them may know that it is easier to dissolve a solid in powdered form than in lump form. Most of them also know that stirring helps solutes go into solution. They will not, however, be able to correlate the above two observations about 'stirring' and 'powdering' into a hypo-

thesis about *how* solids get dissolved in a solvent. This has been attempted here in the following three sub-concepts.

1(a). SOLUTIONS TEND TO BE OF UNIFORM STRENGTH THROUGHOUT

Typical solutions which have set for some time are the same strength throughout their volume. Thus, a sugar solution is equally sweet in all its regions. Activities such as those below will help students grasp this idea.

Investigation

How does potassium permanganate dissolve in water?

Materials required
potassium permanganate crystals
glass tumbler

Wrap a few crystals of potassium permanganate in piece of paper and put it inside a glass tumbler. Add water to the tumbler very gently so that the crystals are least disturbed and moved. Discuss with children what they observe. They will probably be able to tell that potassium permanganate dissolves in water and colours it pink. Discuss the relative intensities of colour in different regions of the solution. Why is the pink colour initially densest near the crystals as in Fig. 5-19? How does the distribution of colour intensities change after some time? Help them understand that during solution, potassium permanganate crystals break up into tiny particles which impart a pink colour to the water. Encourage children to understand how these small particles spread uniformly throughout the water and thus give it a uniform pink colour. Let children also observe that the tiny particles are so small that they cannot be seen or handled. The mixing of these small particles of the solute till they are uniformly distributed is called 'diffusion'.

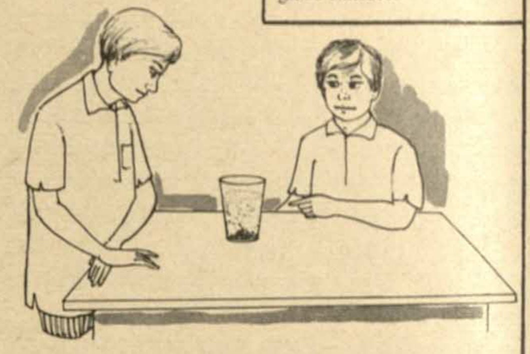


Fig. 5-19a

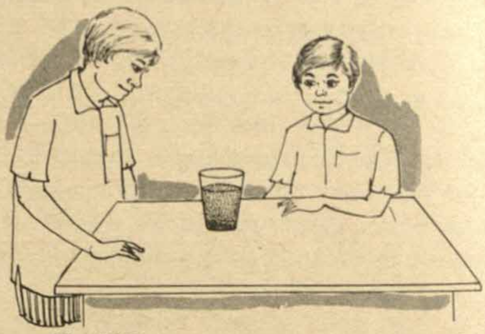


Fig. 5-19b

Fig. 5-19a, b
Potassium permanganate dissolves in water. After a while the dissolved material spreads uniformly through the water.

In the above activity, children can observe diffusion easily because the solute particles impart a colour to water. There are solutes that impart a characteristic *taste* to water. Sugar and salt are examples. Diffusion of solutes in these cases can be detected by tasting.

Investigation

How does cane-sugar spread throughout water?

Materials required
cane-sugar
tumbler

Put some crystals of cane-sugar (or better, one large sugar cube or a small piece of *mishri* in a glass tumbler). Gently pour water over it. Invite children to taste the upper layers of water. They will find it tasteless. Repeat the tasting of the upper layer of water every 30 minutes. Discuss with children why the top layer tastes progressively sweeter and why the sugar cube continuously diminishes in size.

Children usually know from experience that it is easier to dissolve sugar in water if it is first powdered. Secondly, dissolving takes place more rapidly if the water is stirred. Children can be helped to understand the significance of these observations through the following discussion.

Discussion

How does powdering of sugar help dissolve it?

Materials required
3 glass tumblers
mishri
crystalline sugar
powdered sugar

Pour a little water into three glass tumblers containing respectively *mishri*, crystalline sugar and powdered sugar. Stir the three samples of water equally. Show that while powdered sugar dissolves easily, the *mishri* takes longest to dissolve as shown in Fig. 5-20.

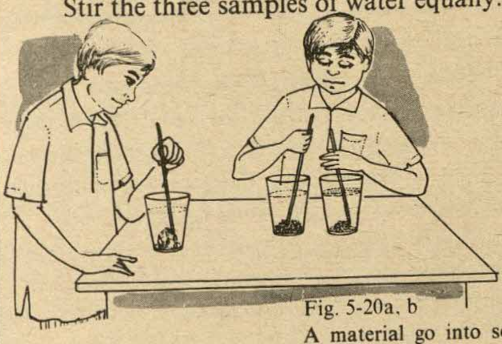


Fig. 5-20 a

Fig. 5-20b

Fig. 5-20a, b
A material go into solution more quickly if it is broken up into small pieces.

Discuss how two processes are important when sugar crystals dissolve in water : (i) a crystal breaks up into finer and finer particles as it gets dissolved (ii) these tiny particles are distributed uniformly through water. Powdering helps the first process and stirring helps the other.

Here is an activity that will help children observe that stirring quickens dissolving.

Investigation

How does stirring help dissolve sugar in water?

Materials required
2 glass tumblers
crystalline sugar

Put a teaspoonful of crystalline sugar in two glass tumblers containing equal amounts of water. Ask a student to stir water in one tumbler with the spoon. He will observe that sugar dissolves more quickly in this tumbler than in the one which was not stirred.

Investigation

Is sugar more soluble in plain water than in a solution of sugar in water?

Materials required
2 tumblers
sugar

Fill two tumblers about half with water. Add 4 teaspoonful of sugar to one of these tumblers thus making it a strong solution. Stir and dissolve the sugar. Now invite a boy to add one teaspoonful of sugar to each of these tumblers. Ask him to shake the two tumblers and observe in which tumbler sugar dissolves first. He will find that plain water dissolves the sugar first. Help children conclude that as solutions become stronger, it gets difficult to add more of the solute and make it dissolve.

1(b). DISSOLVING A MATERIAL IN A LIQUID OFTEN PRODUCES PRACTICALLY NO INCREASE IN VOLUME

Children have observed that a solute breaks up into tiny particles during dissolution. But this is not a complete description of dissolving. Even before solution, materials —both the solute and the solvent exist as tiny invisible particles separated by small spaces. What appears as breaking down of the solute crystal into tiny particles is really the separation of the small invisible particles of the solute crystal. Frequently these particles of the solute enter into solution, yet produce little or no increase in the volume of the solvent. Children can be helped to develop this understanding through the following activities.

Investigation

How does the volume of water change when sugar dissolves in it?

Materials required
glass cylinder
sugar
paper strip
glue

Fill half of a tall cylinder with water and paste a paper-strip along its height. Mark the level of water on paper. Dissolve 3 or 4 spoonfuls of sugar in the water. The children will observe that there is practically no increase in volume when sugar has dissolved in water as shown in Fig. 5-21. Discuss with children what space the sugar particles are now occupying. Since there is practically no increase in volume the small particles of sugar must have been accommodated in some previously existing vacant space. Help children understand that water consists of tiny particles somewhat separated from one another. The tiny particles of sugar which dissolve in the water are in these spaces.

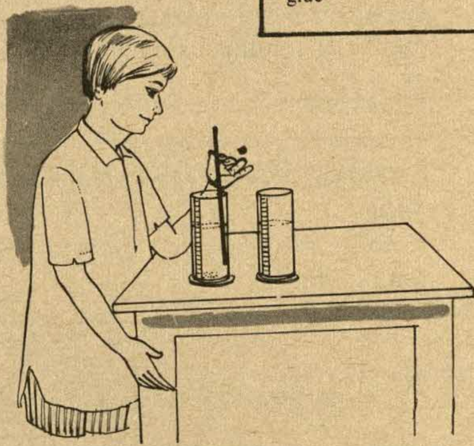


Fig. 5-21
The volume of water does not change when some sugar dissolves in it.

Show to children how sand particles can be accommodated between marble balls filled in a tumbler. Discuss the analogy with the observation in the previous activity.

1(c). MOST SOLIDS ARE MORE SOLUBLE IN HOT WATER THAN IN COLD WATER

Many solids dissolve in water, but their solubilities differ. Solids are generally more soluble in hot water than in cold. Through the following activities the children can be helped to grasp the idea that temperature affects the solubility of a solid.

Investigation

How does heating of water affect the solubility of sugar and saltpetre?

Materials required
2 glass tumblers
2 dishes
sugar
saltpetre

Prepare two glasses containing equal volumes of water. Place some sugar in a dish and an equal quantity of saltpetre in another. Invite a child to add the sugar to one tumbler and

another child to add saltpetre to the other tumbler. These solids should be added in small quantities, and the water stirred each time. After some time the children will find that some sugar or saltpetre remains undissolved even after continuous stirring for several minutes. Invite children to see what happens when the solutions are heated. The undissolved portion of solid dissolves. If heating is continued further more of sugar and saltpetre can be dissolved.

Ask the children to experiment in the above way with the following solids:

soap pieces, soap powder, washing soda, bleaching powder, lemon drops.

2. ALL MATTER IS MADE UP OF SMALL PARTICLES CALLED MOLECULES

Children have made some observations about the process of solution. They have seen how the solute breaks up into tiny particles and how these particles diffuse throughout the solvent water. They may now be helped to make a guess to explain these observations. In the following three sub-concepts one such hypothesis is discussed which is known as the *kinetic-molecular theory*. It assumes that all matter is made up of small particles called *molecules*.

2(a). MOLECULES ARE SO SMALL THAT THEY ARE NOT VISIBLE TO THE NAKED EYE

Children have seen that crystals of sugar disappear on being dissolved in water. They know that crystals of sugar break into tiny particles during solution. But children may wonder why these particles are not visible to them. The following activities would help children understand that when a solute dissolves in water it breaks up into particles so small that they cannot be seen by naked eye.

Discussion

How can some small things be made visible by special arrangements?

Ask children if they have seen dust particles floating in the air of a darkened room when sunlight enters it through a hole. Discuss why dust particles are not ordinarily visible. They are so small that they cannot be seen without some special arrangement. Help children understand that the molecules are so small that *all* arrangements to make them visible to the eye fail.

In connection with other methods for making small particles visible, show children a magnifying lens. Let them see some small particles (e.g., pollen grains, sand particles and ants), through this lens. Help them find out roughly how much bigger a particle appears through the glass than without it.

Discuss with children that even such a small particle as a pollen grain has billions of molecules. To see the molecules one would need a device capable of magnifying many billions of times.

2(b). THERE IS SPACE AMONG MOLECULES

Children have seen that salt and sugar dissolve in water without an appreciable increase in volume. This suggests that there are spaces among molecules of water. The following activities will help further in developing among children this understanding about spaces between molecules.

Investigation

How are solute molecules accommodated in spaces between solvent molecules?

Materials required
glass marbles
tumbler
sand

Fill a tumbler with glass marbles up to its top. Show to children that more marbles cannot be put inside the tumbler. Let children see if some sand can be put inside the tumbler. Help children observe that sand particles are being accommodated in the spaces between glass marbles as shown in Fig. 5-22. In this model, the glass marbles correspond to the molecules of water, and the sand grains to the molecules of a solute

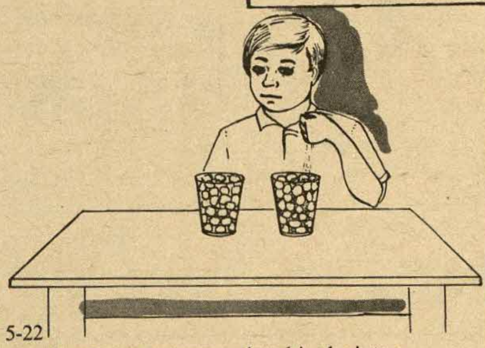


Fig. 5-22
Solute molecules are accommodated in the intermolecular spaces of the solvent molecules.

2(c). THE MOLECULES THAT MAKE UP MATTER ARE ALWAYS IN MOTION

Every piece of matter consists of an extremely large number of molecules. The molecules are attracted towards one another. The force of attraction is not due to some binding material between the molecules such as there is between particles of a *laddoo*

bound by jaggery. The molecules are attracted by electrical forces. The molecules differ from the small pieces bound as a *laddoo* in another way also. The grains do not move in the *laddoo* with respect to one another. Their respective positions are fixed. Molecules, on the other hand, vibrate randomly in a limited space of their own. Children may be helped to comprehend this idea through the following activities.

Investigation

How does a particle move about a particular position?

Material required
string

Stretch a string between two fixed points or simply hold it stretched between your hands. Mark three points with ink on the string. Pull the string downwards and then release it. Show the vibrating inked spots to the children. Discuss with children any difference the spots may show in their extent of vibrations. Help children understand how the spots are moving but only about their original position as shown in Fig. 5-23. Discuss how different this movement is from that of a rolling ball. Challenge children to imagine that molecules of a solid are incessantly undergoing such motions about their positions.

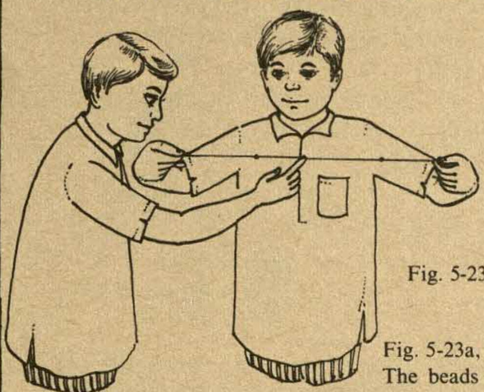


Fig. 5-23a

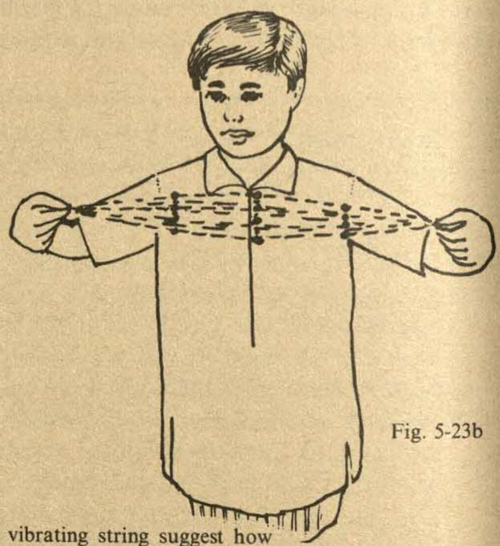


Fig. 5-23b

Fig. 5-23a, b
The beads on this vibrating string suggest how a particle can move about a central position.

Discuss with children about the movement of dust particles due to constant kicking by air molecules. Here the particles are made to move by invisible molecules in the air. This indicates that molecules are in motion.

Children can now visualize that molecules in any piece of matter are in ceaseless motion. They may be asked to suggest what would happen to molecules in motion if they are separated only by small spaces. Some children, at least, will suggest that the molecules will collide with one another.

Discuss with children how such collisions help a sugar cube dissolve and diffuse in water even without shaking.

Discuss why the fragrance of perfume spilled over cloth or paper spreads throughout the room.

For Better Understanding

The concepts and sub-concepts in this unit at this class level have been organized in a way different from many portions of this Teacher's Handbook. It is well for the teacher to have this organization clearly in mind and to help make it clear to the students, too.

In the first major concept there has been a series of simple observations—activities selected so as to reveal something of the molecular structure of matter. The idea is NOT simply to STATE the molecular theory. Instead evidence is gathered on the basis of which students can be helped to DEVELOP the beginnings of the theory. This is the role of the first major concept of this section. Such evidence has been found in observations of the diffusion of solutes in their solvents, in the increase of solubility of most solids with increase of temperature, and in the fact that many solids dissolve in water without a great increase in volume. There is other evidence also available to these students. In Unit 2 'Air, Water, and Weather', and in Unit 4 'Energy and Work', class III and IV students have already learned about the expansion of materials when they are heated. This is also evidence which helps support a simple kinetic molecular theory of matter.

The second major concept of this section consists of the beginnings of a statement of the modern kinetic molecular theory. Teachers should remember that it is only the beginning. But it is a sound beginning, and it is based on the actual observations which students have been making. It will be developed further at higher levels. Students often wonder why it is that scientists are confident about the existence and the behaviour of molecules when they have never seen these tiny particles. The theory is accepted not on the basis of molecules really seen in motion. It is accepted because it explains so nicely many things which actually happen—things like solution and diffusion and thermal expansion. Scientists believe in molecules only because of a large body of indirect evidence. Teachers should try to get students in the frame of mind to believe the theory for the same kinds of reasons.

Scientists at Work

Scientists make hypotheses to explain the behaviour of matter

You have already learned that only a few hundred years ago alchemists were experimenting to find a method for converting iron and other such cheap metals into gold. Behind all their activities was the conviction that different materials were simply different arrangements of a few primary substances. To them the possibility of converting iron into gold seemed quite reasonable. Even today scientists have a set of well-tested beliefs—hypotheses, theories and laws—as the foundation of their work.

Besides beliefs, a scientist needs apparatus and laboratory technique. The alchemist had some simple type of vessels in which he could heat or cool substances. In spite of ill-conceived notions and crude laboratory techniques, alchemists were still able to discover some alkalis, acids and other compounds because they had a keen sense of observation.

Any material object may be viewed upon from two angles: that it is a *piece of matter* and that it is a *kind of matter*. Some beliefs about the kind of matter have already been discussed. For example, Aristotle and many after him regarded all materials to be of ultimately the same basic kind. Different materials were mixtures, of the same primary substances, fire, air, earth and water.

People had also been speculating about the nature of a piece of matter—say a piece of chalk or a wooden block or a glassful of milk or a balloonful of air. In some of these cases at least, matter appeared to be discontinuous and composed of small particles in constant motion. Then is all matter composed of particles in motion? Or, is any material object one continuous piece from one end to the other?

Nearly three thousand years ago, there were thinkers preaching belief in the discontinuity of matter. Kanada is regarded as the originator of such ideas (called *Paramanuvada* or the atomic theory) in India. Among Greeks, Democritus (468-370 B.C.) was the most active supporter of these views. He was a disciple of Leukippos. The actual writings of both Leukippos and Democritus are now lost. One can, however, know about their views from the works of Aristotle. According to him, Democritus thought that the particles of matter (atoms) are hard, and have a definite size and form. They are invisible because they are very small. They have no colour taste or smell because these are subjective properties. They are in ceaseless motion. The universe is nothing but an immense vacuum in which multitudes of atoms move.

Interest in the atomic theory of matter was again revived by the Russian scientist M.V. Lomonosov (about 1740) and the English chemist Dalton (about 1805). It was put into near modern form by the Italian physicist Avogadro in 1911. The major contribution of

one of these scientists is the idea that the atoms of one kind are all alike in weight and properties.

So important has been the role of atomic theory in the development of chemistry that it is considered to be the cornerstone of this science. It is interesting and important to realize that the modern atomic theory of the structure of matter has been the work of many scientists from many different parts of the world. Development of this theory has been going on for hundreds of years. Our understanding of the structure and behaviour of matter will doubtless continue to improve in the years and centuries to come.

UNIT 5

MATTER AND MATERIALS

CLASS V

Overview

In the previous class children have learnt about a hypothesis regarding the composition of matter. The hypothesis, namely, *kinetic-molecular theory*, was conceived to explain observations of the phenomenon of solution formation. In Unit 5 at class V level some more observations about the three states of matter are discussed in the light of the kinetic-molecular theory previously developed.

The first major concept is about the shape-volume characteristics of the three states of matter in the light of kinetic-molecular theory. These characteristics had already been observed and studied previously. A return to the study of these properties in class V helps in the development of kinetic-molecular theory. As a result the theory is modified to include the different types of molecular motions in solids, liquids and gases. The second major concept is again about the properties of the three states of matter. Here the treatment is in terms of the energy of each state of matter. Variety in molecular motions of solids, liquids and gases helps explain the characteristics of matter in its three states.

With increasing temperatures molecular energies and, therefore, molecular motions also go up. Thus, refinement of the kinetic-molecular theory to the level of molecular energy concept helps in explaining some observations concerning temperature. These observations are about comparative diffusion of dyes in water at different temperatures and about thermal expansion of matter in solid, liquid and gaseous states. These observations have been discussed in the third major concept of this unit.

1. THE PROPERTIES OF THE THREE STATES OF MATTER CAN BE EXPLAINED BY THE KINETIC-MOLECULAR THEORY

The children have learned that molecules are in motion. The energy of motion is called *kinetic energy*. The water of a mountain stream pushes one's feet forward because it has kinetic energy. Since molecules are moving, they have also a kinetic energy associated with this motion. The following sub-concepts can help children understand how the kinetic-molecular theory explains the properties of the physical states of matter.

1(a). THE MOLECULES OF SOLIDS ARE PACKED TOGETHER TIGHTLY; THEY VIBRATE WITHOUT PERMANENTLY LEAVING THEIR PLACES

In solids, the molecules are securely held to each other and their movement is only a vibration. The forces of attraction among the molecules of a solid are so great that the molecules are not able to go far from their relatively fixed positions. That is why solids are rigid, and they maintain their shape. Children can be helped to understand this through the activities given below.

Investigation

Why do solids have a definite shape and volume?

Invite four children to pretend they are the four molecules of a very tiny object. They should hold hands or link arms to form a small ring. Their arms correspond to the invisible forces which hold molecules together. Now permit them to stoop or stand erect or to jump and dance around as shown in Fig. 5-24 provided they do not release hands and do not leave their places. Help them realize that this is much the way molecules behave in a solid. They can move about within a limited space but they can't move out of a general position in relation to their neighbours.

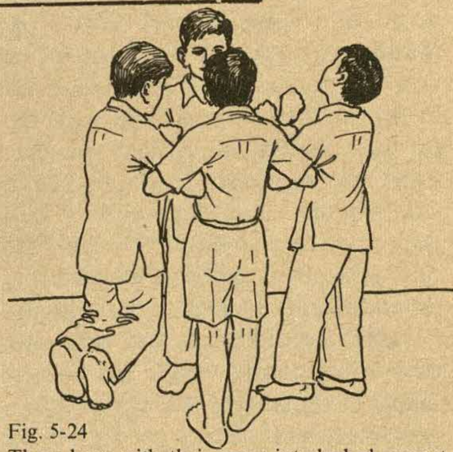


Fig. 5-24
These boys with their arms interlocked cannot change their positions very much. In a similar way, the molecules of a solid are quite firmly bound together.

Ask children to imagine a stack of bird cages, each with a bird inside. Each bird is free to move, but only in a limited distance. In a somewhat similar way, molecules in a solid can vibrate, but cannot move from place to place.

1(b). THE MOLECULES OF A LIQUID ARE CLOSE TOGETHER, BUT ARE FREE TO SLIDE OVER EACH OTHER

In liquids the force of attraction among molecules is weaker than in solids. They can slip and slide over each other but they do not separate. The following activities will help the children to understand this.

Investigation | **How do liquids change their shape?**

Invite eight children to pretend they are molecules of a very tiny droplet of a liquid. Let them hold each other's hands. They should be a little farther apart than as in Fig. 5-24. Invite them to stand in one long row. Challenge them to rearrange themselves without letting go their hands, into two rows of four each, as in Fig. 5-25. They can do this by moving past each other as the illustration suggests. Help them realize how children are freer to move about in this activity as compared with the previous one. Encourage them to understand that the molecules in a liquid can similarly move about more freely than molecules in a solid. They can slide past each other, though they are never separated from each other of the group. Because the molecules can slide past each other, liquids have no definite shape. Because they are never completely detached, they do have a definite volume. See also Fig. 5-28.

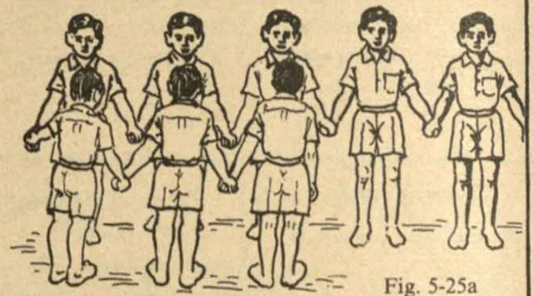


Fig. 5-25a

Fig. 5-25a, b
These eight boys can change the shape of their formation without letting go of their hands. The molecules in a liquid behave in somewhat similar way.

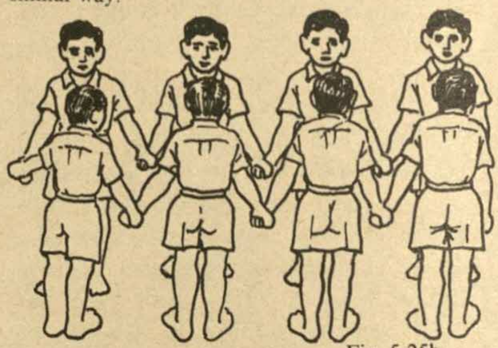


Fig. 5-25b

Remind students how til-laddu *is prepared from* til *seeds and syrup. When the syrup is hot, the seeds are free to move, something like the molecules of a liquid. When the syrup cools, the sweet-piece is like a solid.*

1(c). THE MOLECULES OF A GAS ARE FAR APART AND COMPLETELY FREE TO MOVE

In gases the molecules are far apart and are in violent motion. They strike each other frequently but they are not attracted towards one another. Children can be helped to understand this through the following type of activities.

Discussion

Why can a gas change its shape as well as its volume?

Ask some children to pretend they are the molecules of a tiny sample of gas. They should not hold hands. They should move around violently. They should be well separated from each other. Also they should be more or less evenly scattered throughout the room. In this way they are making a crude model of gas molecules.

Discuss why the fragrance of perfume kept in an unstoppered bottle spreads quickly throughout the room. Why does stoppering prevent the spreading of fragrance?

2. THE PROPERTIES OF THE THREE STATES OF MATTER CAN BE UNDERSTOOD IN TERMS OF THEIR ENERGY

Children have learnt that all matter—solid, liquid or gas—is made up of tiny, invisible moving molecules separated by spaces. They have seen that molecular motion may be of different types. Molecules in a solid move (vibrate), never getting far from a fixed position. Molecules in a liquid can move past each other but they cannot get away from their neighbours completely. Molecules in a gas move much more freely than molecules in a liquid. They are free to separate widely from each other.

A substance can exist in the three physical states—solid, liquid or gaseous. Why should molecules of water have different types of motion in the form of ice, liquid water, or steam? The answer is in the energies of molecular motion. Every moving object has an energy associated with its motion. Molecules too, have energies. Children here will be helped to understand that molecular motions in ice, water, and steam are of a different sort because energies of molecules in the three physical states—solid, liquid and gaseous—are different.

2(a). MOLECULES OF A SOLID DO NOT MOVE FROM PLACE TO PLACE BECAUSE THEY HAVE VERY LITTLE ENERGY

Solids have a definite shape and a definite volume. Children have seen that this is because molecules in a solid move slowly and only about a certain fixed mean position. Since molecules cannot move out of their respective positions, the shape in a solid does not change. Children may be curious to know why molecules in a solid move so sluggishly. This is because molecules in a solid have very little energy. The following activities can help children develop this understanding.

Investigation	**Why does a stronger boy throw a ball faster and farther away than a weaker one?**	*Material required* ball

Invite two children—one big and strong and the other quite small—to compete in throwing a ball. The ball thrown by the stronger boy moves quicker and farther because he can put more energy in throwing the ball. Help children understand that molecules in a solid are moving slowly and within a very short distance range because they have less energy.

Encourage children to cite cases where differences in the speed of motion are related to differences in energies being put into motion. Thus a ball can be thrown gently with a small amount of energy, but it takes more energy to throw a ball swiftly.

2(b). MOLECULES OF A LIQUID ARE ABLE TO SLIDE PAST ONE ANOTHER BECAUSE THEY HAVE MORE ENERGY THAN MOLECULES IN A SOLID; HOWEVER, THEY DO NOT HAVE ENOUGH ENERGY TO SEPARATE FROM ONE ANOTHER

Molecules are very small. They are very large in number, even in a small piece of matter, *e.g.*, an ordinary drop of water contains more than 1,500,000,000,000,000,-000,000 water molecules. They are in motion, and their rates of movement vary. The children can now learn that moving objects, however small, possess considerable energy if they move with high speeds.

Investigation	**Does an object acquire more energy when it moves faster?**	*Materials required* stone paper

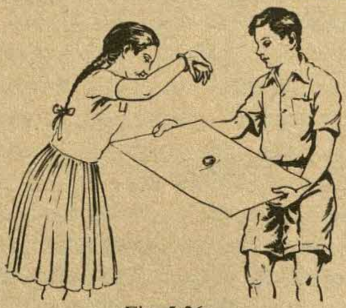


Fig. 5-26a

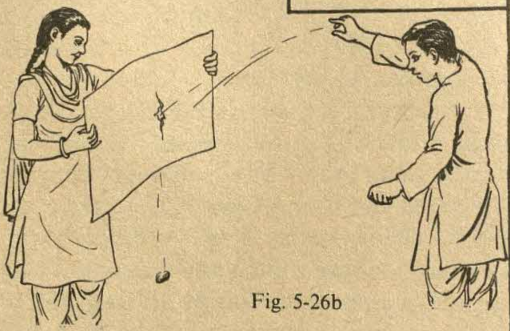


Fig. 5-26b

Fig. 5-26a, b
The stone which was thrown moves faster than the stone which was dropped. The faster moving stone has more energy.

Allow a small stone to drop on to a piece of paper from a height of about 1 cm. The size of the stone and its height should be such that the paper does not get torn. Now strike the stone against the paper with great speed. The paper tears as shown in Fig. 5-26. Why does it happen? Rapidly moving things have more energy.

Discuss why it is difficult to stand in a rapidly flowing mountain stream. The running water strikes the person standing in the water and transfers some of its energy to him. He has to struggle to resist movement by this energy. It is easier to stand in the river water of the plains because there the water moves slowly, and has only a small amount of energy.

Investigation

Why does a rapidly moving cork from a toy-gun pierce paper?

Materials required
toy-gun
cork
paper

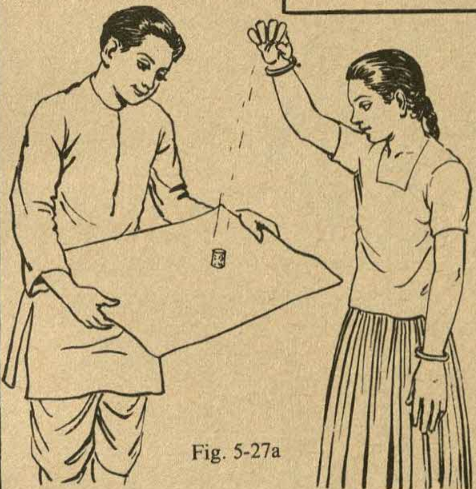


Fig. 5-27a

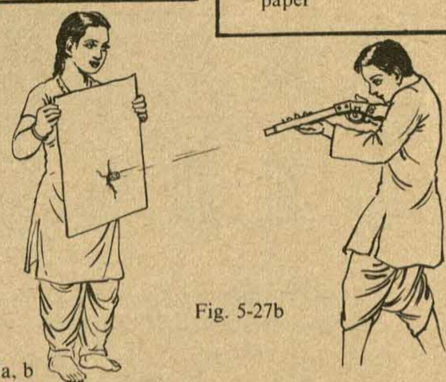


Fig. 5-27b

Fig. 5-27a, b
A rapidly moving cork from a toy gun tears the paper; a slowly moving one does not

Ask a child to drop a cork on a piece of paper from such a height that the paper is not pierced. Now fit the cork into the mouth of a toy-gun. Allow the cork to fly and strike against a piece of paper held vertically in the hands. The paper is pierced as shown in Fig. 5-27. Help children understand that the swiftly moving cork from the toy-gun had a greater energy and therefore pierced the paper.

Help children arrange a similar experiment with a bow, an arrow and paper.

Discuss how even a small bullet flying with a high speed from a rifle has very great piercing energy.

Children thus find that the energy of a moving molecule increases with its velocity. In general, energies of molecules increase with a rise in temperature. Hence the velocity of molecules also goes up with increasing temperatures.

In contrast with gases, liquids have a definite volume. How can this be explained on the basis of energies possessed by liquid molecules? The following activity will be found useful in this connection.

Investigation

How do molecules in a liquid change position so that shape changes, while volume does not?

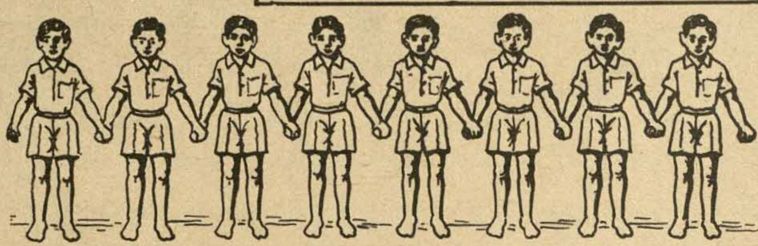


Fig. 5-28a

Fig. 5-28a, b
These boys have shifted their position and changed the shape of their formation Yet they still occupy the same space. Molecules in a liquid behave in a somewhat similar way

Draw two lines on the ground about a half metre apart. Invite sixteen children to stand between these lines, as in Fig. 5-28. Let each one hold his neighbour's hands and keep some space between himself and his neighbours. Roughly measure the area children are occupying for standing on the ground. Ask them to form a double row of eight boys each without detaching their hands. Estimate the area on ground now occupied by children. They will find it to be almost equal as shown in

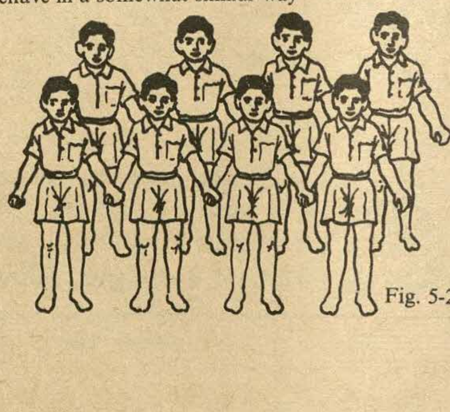


Fig. 5-28b

the sketch. Ask them now to rearrange into a square formation. Compare the situation with water being transferred from a flat tray to successively narrower and narrower tumblers. Height or depth increases in both the cases. Help children to discover that space occupied by children remains unaltered even though the shape of the formation changes. See also Fig. 5-25.

Ask children to fill a rubber balloon with sand. Show how the balloon can assume different shapes. Let them realize that the sand grains move past one another during a change of shape. Similarly fill a balloon with water; again the balloon can be made to assume any desired shape.

Discuss why a collection of marbles behaves similarly to a liquid in the above respect. The marbles can change relative positions.

2(c). MOLECULES OF A GAS HAVE EVEN MORE ENERGY THAN MOLECULES OF A LIQUID; THEY ARE EXTREMELY FREE TO MOVE ABOUT

What happens when water changes into gas? Steam occupies a large volume in comparison with the water from which it is formed. The molecules must, therefore, have larger spaces among them. In addition, they have no attraction towards one another. Help the children understand this through the following activities.

Investigation

Why do molecules in a gas move in random fashion?

Materials required
2 bangles
black thread
white thread

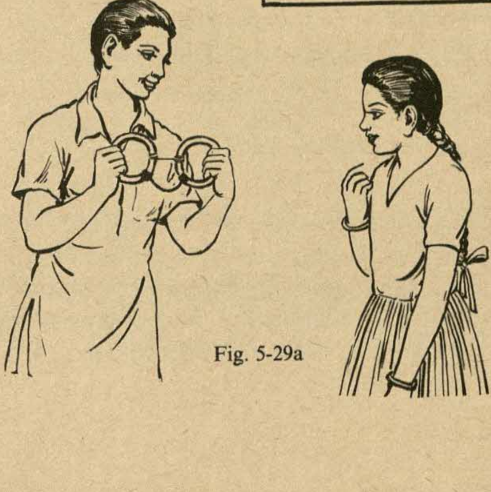
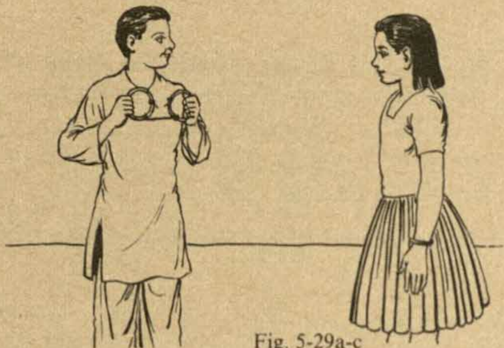


Fig. 5-29a

Fasten two threads—one white and thin, the other black and strong—to two strong bangles, as shown in the Fig. 5-29. Keep the black thread slightly longer than the white one. Invite children to imagine that these two rings represent two molecules of a solid. Show by breaking the white thread that the rings can now be moved a little farther apart and thus have



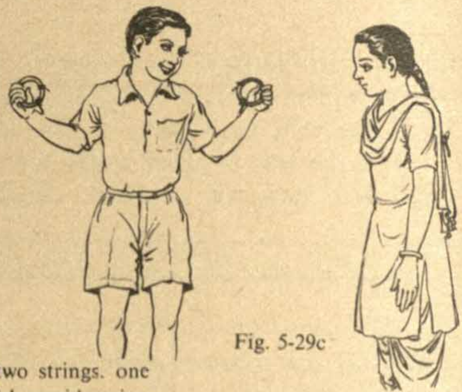


Fig. 5-29b

Fig. 5-29a-c
The bangles are connected by two strings. one stronger than the other. A careful consideration of how the bangles become more and more free as the strings are broken helps students to understand how molecules become more and more free as they acquire more and more energy.

Fig. 5-29c

greater freedom of movement. Explain that there is now only the black thread binding them together. A somewhat similar thing happens when ice melts to form water.

Now break apart the black thread also and show to children that the rings can be moved most freely into any position and now have extreme freedom of movement as there is now nothing binding them together. Help children understand that a similar thing occurs when water boils into steam. The attractive forces working between molecules of liquid water do not exist when water is in the gaseous state. Hence molecules in a gas move in random fashion. This analogy for water molecules is also true in the sense that more energy is absorbed during the change from liquid to gaseous state than during the change from solid to liquid. (The black thread is stronger than the white one.)

Bring out an analogy to help children understand the conspicuous separation of molecules in the gaseous state. Let them imagine a crowd before and after a show. Before the show they are well-ordered. After the show members disperse and move farther and farther apart.

When molecules of liquid water change into water molecules of steam, a change of the type visualized in the above activity occurs. There are forces holding molecules together in liquid in such a way that only its shape changes and not the volume. Heat energy is needed to overcome these forces of attraction. Once this happens (by absorbing heat) the molecules in a gas have greater degree of freedom of movement.

For Better Understanding

The most important factor which limits molecular motion in solids is the strong attractive forces among the molecules. The attractive forces among molecules in a solid are much greater than the attractive forces among molecules of the corresponding liquid. When solids melt only part of these forces are overcome (breaking the white thread). In liquids the attractive forces among molecules are weak enough to permit molecules to slip and slide over each other. Yet they are still strong enough to prevent the molecules from separating completely from one another. (The black thread has not yet been broken.)

In some of the activities used in earlier parts of this unit crude analogies have been used to make the forces among molecules clear to children. Such forces have been illustrated with string, syrup, and even bird cages. Teachers should realize, however, that the forces among molecules are invisible. Actually the forces are electrical in character.

The nature of the electrical forces is illustrated in a simple and common activity. One combs his hair with a plastic comb; it gets an electric charge. The comb gets a negative charge and the hair gets a positive charge. Since opposite charges attract each other the comb and the hair tend to stick together. They cling to each other due to invisible electrical forces. In a similar way the positive and negative charges of molecules tend to make them cling to each other in solids and in liquids. In gases, however, the molecules are so far apart that the invisible electric forces have no effect.

Magnetic forces and the forces of gravity are also invisible. However, it is primarily the electrical forces among molecules which accounts for the properties of solids, liquids, and gases.

3. SOME OBSERVATIONS CONCERNING TEMPERATURE CAN BE EXPLAINED BY THE KINETIC-MOLECULAR THEORY

Children have built up some ideas about the structure of matter around the concepts underlying the words: 'molecule', 'molecular energies','molecular motion', and 'space among molecules'. Here children will be encouraged to apply these ideas for explaining some observations concerning temperature They have learnt through the previous activities that molecular energies increase when the temperature of a substance is raised. As the energy of a molecule increases it moves faster and hits harder against its neighbours. The space among molecules becomes greater in this way.

3(a). DYES DIFFUSE MORE RAPIDLY IN HOT WATER THAN IN COLD WATER

It is common knowledge that dyes dissolve and diffuse in water. Only few may, however, have observed that dyes diffuse more rapidly in hot water than in cold water. The following activity will encourage children to interpret this observation.

Investigation

How can rapid diffusion of dyes in hot water be explained?

Materials required
2 glass jars
cloth
string
dye

Take two glass jars of about the same size. Fill one with cold and the other with hot water. Fasten a piece of tightly woven cloth over the mouth of each jar with a rubber band or thread as shown in Fig. 5-30. The cloth is cupped so that it is just a little above the surface of water. Put 4 crystals of some dye over each of these cups. Push down the cups so that they just touch water. Ask children to observe and describe what they see. Discuss why the dye diffuses more rapidly in hot water. Help children understand that molecules in hot water have more energy and are moving faster. Brisker movement of water helps in a quicker diffusion of the dye in water.

Fig. 5-30
Solutes diffuse more rapidly in hot water than in cold water.

Discuss why, for the preparation of a cold drink at home, it is better first to dissolve sugar in water and then put ice rather than to put ice in first and then dissolve sugar. (Sugar dissolves quicker in warmer water.)

3(b). LIQUIDS AND SOLIDS EXPAND WHEN THEY ARE HEATED

All matter expands on heating. This is because molecules gain energy upon heating and begin to move faster. They also strike harder against one another at higher temperatures and therefore the spaces among molecules increase. Increase in the size of these spaces shows itself as expansion of matter. But liquids expand more than solids. How can this be explained on the basis of molecular structure of matter? The following activities are helpful in this connection.

Investigation

Do both container and liquid expand when heated?

Materials required
cork with a bore
glass tube
jar with hot water
ink

Have a bottle fitted with a cork and a glass tube as shown in Fig. 5-31. The bottle is filled with water coloured with ink up to some height in the glass tube. Immerse the bottle in hot water. Help

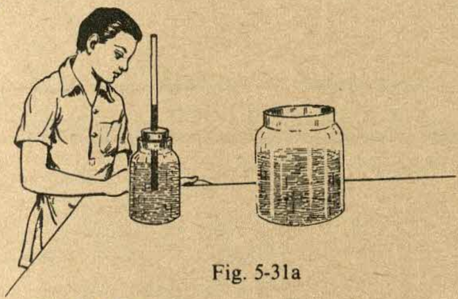


Fig. 5-31a

Fig. 5-31a, b, c
When the bottle is put in the can of hot water, the glass bottle expands first, and the liquid level falls in the tube. After a short time, the water inside the bottle also gets warm. Then the water expands and its level rises in the tube.

children to observe that the level of water in the tube to begin with falls but soon rises above the initial level. Discuss with children that the first fall in level as shown in the sketch is because glass of the flask expands. Soon the water within the flask also gets heated and expands. Since expansion of water is greater than the expansion of glass, the level of the water in the flask rises when water gets heated up.

Fig. 5-31b

Fig. 5-31c

Discuss with children how the above principles apply in the working of a thermometer.

3(c). GASES EXPAND WHEN THEY ARE HEATED; THEIR EXPANSION IS MORE THAN THAT OF SOLIDS AND LIQUIDS

Gases expand much more than either liquids or solids upon heating. It is common experience that during the extreme heat of summer months, tyres of vehicles running on hot roads often burst. This is because the air within the tyre is heated up strongly. Being gaseous it expands enormously. The solid tyre also expands upon being heated, but this expansion is much less than that of air. Heated air thus develops a pressure that bursts the tyre. Through activities like the following, children can develop an understanding about the great expansion of gases upon heating.

Investigation

How much do gases expand on heating ?

Materials required
glass bottle
cork with a bore
glass tube
glass jar
coloured water

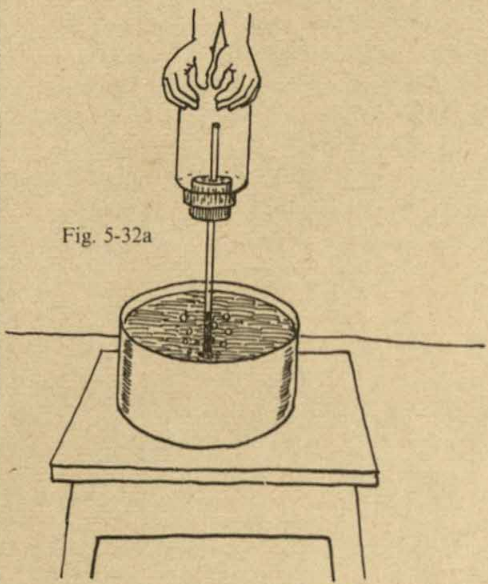


Fig. 5-32a

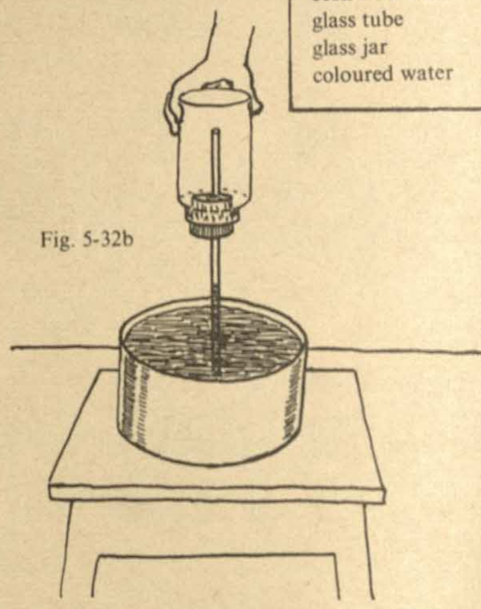


Fig. 5-32b

Fig. 5-32a, b
When the air in the bottle is warmed, it expands; when the air cools, it contracts.

Prepare a glass bottle fitted with a cork having a single hole. Insert a glass tube into the hole. Make the connections air-tight by putting melted wax over them. Place the bottle in a glass jar filled with some coloured water as shown in Fig. 5-31. The glass bottle is warmed by wrapping the hands closely around it. Help children observe that air bubbles are coming out because air expands upon heating. After some time remove the hands and allow the bottle to cool. Coloured water will rise in the tube. Discuss with children how the expansion of water (a liquid) was much less in the previous activity of Fig 5-31 as compared to the expansion of gas in this activity.

Ask children to suspend inflated balloons on top of a fire so that the balloons do not catch the flame. Help them to explain their observations (they will find that the balloons burst). Correlate this observation with that of the bursting of vehicle tyres in summer.

Discuss with children why is it that even small quantities of water on boiling produce steam that fills up the entire space within the container. Steam exhibits greater expansion than either heated water or the metallic container. Help children understand that there are no forces of attraction among molecules in a gas.

For Better Understanding

When a gas is heated, its molecules gain energy and move faster and hit harder against one another. Since there is no attraction among them, they separate rather easily. They continue to move faster and faster; they move farther and farther apart as they are heated more and more. In liquids there are appreciable forces among molecules. Therefore, heating does not force them apart so far. In solids the attractive forces among molecules are greater still. Hence they move apart even less, upon getting more energy. Hence with them the expansion upon heating is least

Scientists at Work

Benjamin Thompson and the concept of molecular motion

There are certain words that are very familiar and yet very difficult to define. Nevertheless, definitions cannot be avoided. The definition underlying the question 'What is heat ?' Illustrates this problem.

About two centuries ago, heat was considered to be a fluid (named *caloric*) that flows from a hot body to a cold body. The fluid was supposed to be weightless, since there was no loss or gain of weight after the flow of heat to or from bodies.

Benjamin Thompson made some important observations that started a chain of inquiries leading to a new concept about the nature of heat. You may now be interested to know who Benjamin Thompson was and what his revolutionary observation was.

Benjamin Thompson was born and brought up in a small town in America. He was very intelligent and an eager reader. In 1775, during the American War of Independence, he sided with the British. He left for England and there secured an important government post. In 1783, Thompson went to Germany. During his fifteen years' stay there he served as a supervisor in a factory where brass cannons were made. In addition to his official duties he carried out many scientific experiments. The most important of these concerned the nature of heat.

Benjamin Thompson (by then known as Count Rumford) was supervising workmen boring brass cannons in a German arsenal. A workman by chance touched one of the cannons with his

bare hand. Thomspon observed that a blister was formed on the worker's hand. When some brass chips from the boring were put into water, it began to boil.

If the theory that heat is a fluid were correct, Thompson argued, what was the source of heat in this case? During his further experiments, Thompson found that any amount of heat could be obtained from friction by keeping the things moving.

Thompson seriously doubted the firmly held belief that heat is a fluid flowing from a hot body to a cold one. Since heat was apparently produced from motion, he suggested that there are small particles in motion within the bodies. The motions during cannon boring affected the movement of these small particles in such a way that the cannon became hot. The small particles were later on named *molecules*. Heat, according to Thompson, was a kind of energy associated with molecules.

Benjamin Thompson was a bold man in that he could defy the established notion of heat as a fluid, all on the basis of his own observations. He had a good imagination which enabled him to put forward a better and more workable substitute theory. After some time the notion of heat as a fluid was dropped. Traditions die hard however, and we still speak of heat as 'flowing' from one place to another.

UNIT 6

HOUSING AND CLOTHING

CLASS I

Overview

The comforts of home are common in the experience of all children. The love of the home is very strong with some young children going to school for the first time. Often the separation of these children from the home requires a great deal of effort. The nursery schools try in various ways to solve this problem.

Attachment with the home is a personal experience to the child. He may not however realize that every other child loves his own home as much as he does. Why should looking at one's house seem to him so much different from looking at his neighbour's? It is because his *house* provides a *home* for him.

How does a house differ from a home? The feeling of comfort and shelter goes with the idea of a home. A home provides the warmth and affection of mother, father, brothers and sisters. A home involves much more than simply the physical surroundings where a child lives.

From his birth a child needs protection and shelter. When he feels hungry, he cries for milk and the mother gives it. This results in an attachment that makes the child comfortable in her presence. Under normal conditions the liking for the mother's presence grows into an attachment with the immediate social environment confined by the four walls of a house. The idea of a home includes this feeling for the social environment of the family. A house is the place where a family lives. It does not include any notion of the social environment. When several families reside in different portions of a house, one may say that there are several homes in the house.

A child likes his house because there live his parents, brothers, and sisters. Besides, he likes it because it satisfies his many physical needs. During the scorching heat of summer, or in the biting winds of winter he needs shelter. His house provides it.

How physical needs are satisfied by a house, has been discussed under three sub-concepts at class I level of this unit. The house gives shelter, comfort and a storing place. The four walls, the roof, the doors and the windows of the house are almost as much a part of his home as are the family members. This will later help him in understanding that even with the same family members, the home environment will vary according to the physical needs and facilities provided in the house.

India needs an intensive *housing* campaign in order to provide a *home* environment which will promote the healthy growth of

children. Children should be helped to feel this through stories and anecdotes rather than have it given as a piece of formal information.

1. MAN BUILDS A HOUSE FOR HIS HOME

The child's immediate environment is his home. In it he finds comfort, shelter and warmth. The child should be made to realize that a good house is a necessity for healthy living. Therefore, the house must be well-constructed. He will learn that good construction not only helps in keeping away heat, wind and rain, but also protects him from his enemies.

1(a). A HOUSE PROVIDES PROTECTION FROM WIND, SUN, RAIN, COLD, AND ENEMIES

Children live in houses. They know where to run when a dog barks or the rain starts pouring. However the idea that the house is providing them with shelter against animals or weather may not be very clear to them. They may be using the concept without actually knowing it. They can be made aware of the idea through activities of the following type.

Discussion | **How does a house protect us?**

Discuss with children such questions as: Where do you live? Why do you need a house to live in? Where do you run, when a dog or a bull starts running after you? Would you like to stay inside the house or out in the sun on a summer day? When there is a storm outside, what would you do in your house to protect yourself? How do you protect yourself and your belongings from enemies and robbers? Help the children realize through answers that the house gives them shelter from wind, sun, cold, and enemies.

Investigation | **Where can I be comfortable—out in the sun or inside a room?**

In summer, let one or two students volunteer to stand out in the sun for some time till they feel hot and uncomfortable. Then bring them into the classroom. Let the children tell where they feel comfortable on a hot sunny day—outside in the sun or in the classroom protected from the sun. See Fig. 6-1.

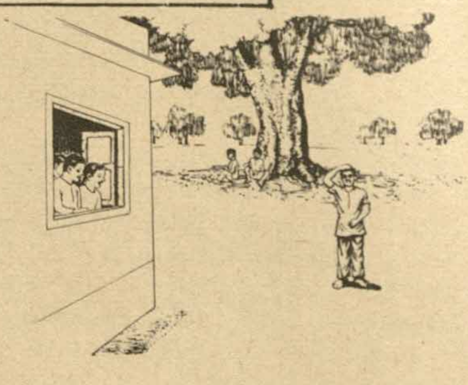


Fig. 6-1
We can feel comfortable in a room while the sun is shining brightly outside.

Let some students of the class do as above during a rainy day. Let the children go round and observe the types of houses in their locality and observe how these protect the occupants from the sun, wind, rain, and enemies and robbers.

Ask the children to collect pictures of huts, tents, brick or stone buildings, etc.

1(b). A HOUSE PROVIDES COMFORT AND CONVENIENCE

Long, long ago when people did not know how to build houses, they shivered when it was cold; they became wet when it rained. Therefore, they searched for protection and comfort and often found shelter in a cave. The cave would keep out some of the rain and cold, and could be warmed up by a fire. A cave could provide some place to sleep, but it was not comfortable. But, ever since people have had homes, they have been trying to make houses more and more comfortable. This can be made clear to children effectively by the type of activities suggested below.

Discussion | **How does a house give us comfort and convenience?**

Engage children in a discussion through questions of the following type: Where would you like to bathe or change your clothes—outside in the open or in a room? Why do you like to take rest and sleep within the house, and not on the street or in the fields? When thirsty or hungry, why is it inconvenient to be at a long distance from your house?

Encourage children to discuss if animals have homes; and if so, of what types. Invite them to give examples of animals which have a home for protection, for comfort, and convenience; and also encourage them to argue about this. Ask children to name five articles in their homes which are intended for comfort and convenience.

1(c). A HOUSE PROVIDES A PLACE TO STORE BELONGINGS

It is common experience that belongings and precious things are safely kept in a house and locked. A home needs many items but not all of them are used at the same time. So the things which are not in immediate need are stored away. The extra

clothes are put in trunks and stored. Sometimes provisions are stored for future use. Thus, a house affords a safe place to store belongings. The activities suggested below will help the children to understand this idea.

Discussion | **How do houses serve for storage?**

Ask children where their mothers store wheat, rice, pulses and other articles of the kitchen. Where do they keep and store the nice clothes for occasional use? Where is fuel stored? Help children realize through this discussion that many household things are stored within the house.

Ask children where they would like to store their collection of toys and dolls.

Invite children to discuss how a house differs from a godown as a storing place. (A godown must be secure, but needs few doors or windows.)

During the construction of a house, a man stores cement in a room, but leaves the heavy iron girders and sand outside. Discuss with children why heavy and comparatively less costly things need not be stored within a house. (High cost of transportation makes their theft unlikely.)

Scientists at Work | **Early man builds a better house**

It is always fun to pretend to be somebody else. That is why plays are so interesting. Let us now imagine ourselves to be members of a prehistoric family awakened one night by the roar of a lion.

Our family is living in a cave. To save ourselves from the fury of the weather and wild animals, we have learned only to move into caves. The fire has just gone out. For fire and its light, our family has to wait till lightning strikes another tree and sets it aflame. The method for producing artificial fire has not yet been invented.

The cave is dark and damp. The floor is uneven. There are stones lying here and there. One is for blocking the mouth of the cave. It is the forerunner of today's door. Other pointed

stones are available to be hurled against animals.

This is the way our own ancestors might have lived many thousands of years ago. In the course of time, man invented several things to satisfy his needs. He learned to use a stone with an edge to fell trees. He learned to kindle fire and use it for various purposes. Metals were discovered and our ancestors learned how to use them.

The cave was a very inconvenient dwelling place. Moreover, caves were not to be found at all places. Sometimes, man had to migrate a long distance to a place where there were no caves. Then, man felt very acutely the need to build a shelter.

Feeling a need is the first condition for any invention. Then there is the availability of materials required for the invention. A third requirement is a store of background knowledge. When man learned agriculture, and some sort of communities grew up as a result of its practice, the need for building a house was felt even more intensely. Possibly the first huts were constructed as an answer to this need. These were constructed either at ground level or above an earth pit to provide greater height. Sun-dried clay bricks were used. The hut frames were covered with material available in the locality: animal skins, leaves, or bark.

As villages grew into cities and cities into states, man felt the urge to have even better houses. Man had discovered that kiln-cured bricks are stronger and last longer. His knowledge of working with stones, clay, wood and plant pigments was now good enough for him to make better houses.

From a hut to a brick house and then to present-day high building called *sky-scraper*, it is the same story. Man feels a need and then uses the materials available in the environment. The biggest step had, however been taken when man decided not to submit to his environment, but to move into a cave for his dwelling. The day man left the cave and prepared the first hut by using materials available in the environment was really a great day in human history.

UNIT 6

HOUSING AND CLOTHING

CLASS II

Overview

In class I children have explored the importance of a house in their lives for providing shelter, comfort and a storing place. Although the primary functions of a house are almost always the same, there is a great variety in the way these objectives can be achieved. One big idea discussed in this unit is that an objective like human shelter can be achieved in a variety of ways.

Discovering variety does not require unusual intelligence. The child needs only to be helped to be an observer of his surroundings. The child at this class level can easily make the observations suggested in the activities of this unit. Even a casual look at the houses of a locality points to the variety in roofs, variety in shape and variety of material. When temporary houses are put up, it is easy to see that they are different from permanent houses.

Man is constantly faced by the conditions of his environment. He can, however, respond to these conditions in two basically different ways. Man can either accept the surroundings as unchangeable and then submit, or he can try to change his environment to fit his needs and desires. Of these two types of responses towards the environment, the one involving attempts to master the surroundings has been the basis of the development of modern housing.

In his quest for mastery over nature, man designs a house. If the place where he lives has a heavy rainfall, he plans a house with sloping roofs. If the surroundings are very hot or very cold, he makes appropriate changes in the design of the house to counteract these hardships of nature. Variety in design is partly a result of man's efforts to mould nature to fit his needs. He builds a house of particular design because he wants to be secure and comfortable in spite of the harsh surroundings.

The history of civilization as a growing victory of man over nature is reflected in the evolution of house-design and house-furnishing. This idea may also be touched upon at this class level. 'Variety' and 'adjustment' are thus two big ideas of this unit, and 'observation' is the chief method of study

1. HOUSES ARE OF DIFFERENT TYPES

A house is built in such a way as to afford shelter from sun, rain, wind, and enemies;

at the same time, it is meant for comfort and convenience. When a man wishes to camp at a certain place, he uses a tent. A tent is a temporary house. It is light enough to be carried about.

There are other types of houses. They differ from one another because they serve man in different ways.

1(a). SOME HOUSES ARE PERMANENT, OTHERS ARE TEMPORARY; THEY MAY BE STATIONARY OR MOVABLE

People who live over a long period of time at one place live in permanent houses such as flats, bungalows, or huts. But those people who have to move frequently from place to place often carry their shelter with them. In such circumstances, tents and trailers are used. These types of shelters are temporary and can be moved easily. The following activity will help the children to understand the idea contained in this sub-concept.

Class Project

How great is the variety in our houses?

Materials required
picture books
magazines

Help the children collect pictures of different types of houses from picture books if available, or from old text-books or periodicals. Let them tell you the type each one of them is: whether permanent or temporary, stationary or movable. If pictures are not readily available, the teacher should draw on the black-board in the manner shown in Fig. 6-2, and then let the children discuss the drawing.

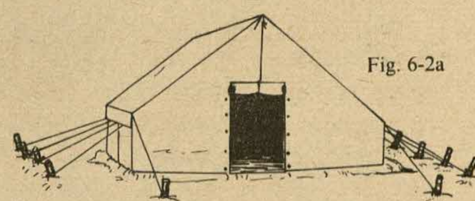


Fig. 6-2a

Fig. 6-2b

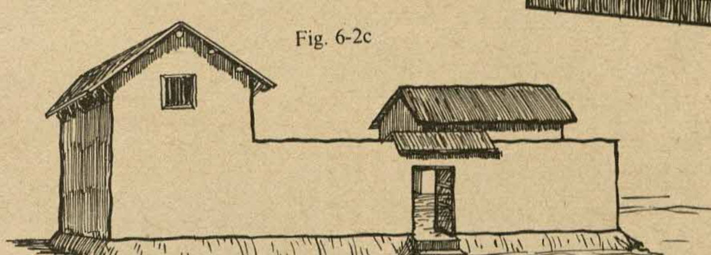


Fig. 6-2c

Fig. 6-2a-d
We have many kinds of houses.

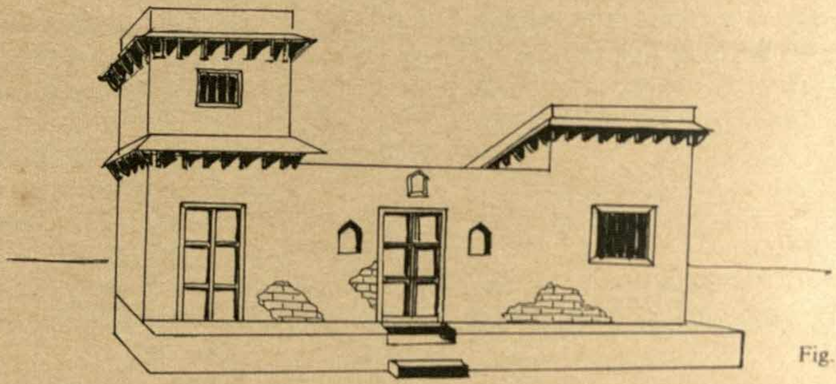


Fig. 6-2d

Discussion

Why are some houses movable?

Discuss with the children why it becomes necessary for some people to have a movable house. Show them a tribesman's house on wheels. Or, make a drawing on the black-board as in Fig 6-3. These people often visit village fairs and do odd types of metal-work.

Fig. 6-3
The tribesman's house is sometimes movable.

Take the children on a trip to a police or military camping site or to a scout camp or an NCC camp. Let them observe how the policemen, the sepoys, the scouts or the NCC cadets live.

Take the class out to visit a road-repairing site, where the workers live in tents or temporary structures.

Ask children if a car or a roofed cart can be called a house. If not, why not? Can a boat be used as a house? Talk to children about the house-boats of Kashmir. See Fig. 6-4.

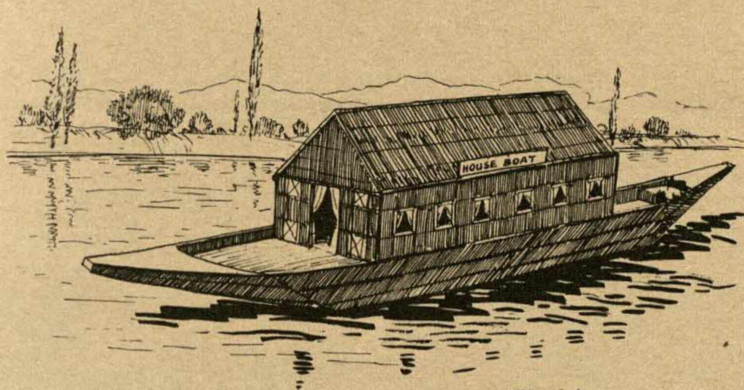


Fig. 6-4
A house is sometimes in the form of a boat.

1(b). HOUSES HAVE DIFFERENT TYPES OF ROOFS

Whether the houses are permanent or temporary, movable or immovable, they have roofs. These roofs are not all of the same type. Some roofs are flat, like the ones modern terraced buildings have. Others may be curved, as those on semi-circular huts. Sloping roofs are also quite common in the villages of this country.

In order to appreciate the variety of house roofs, children can be helped to carry out the following activities.

Class Project

How great is the variety in the roofs of houses?

Make drawings of houses with a flat roof, a curved roof, and a sloping roof on the black-board as in Fig. 6-5. Ask the children to collect the pictures of houses having different shapes of roofs. Ask them to group the pictures under the following headings: *Flat roofs, Curved roofs, Sloping roofs.* Ask the children to question their parents regarding the different types of roofs they have seen.

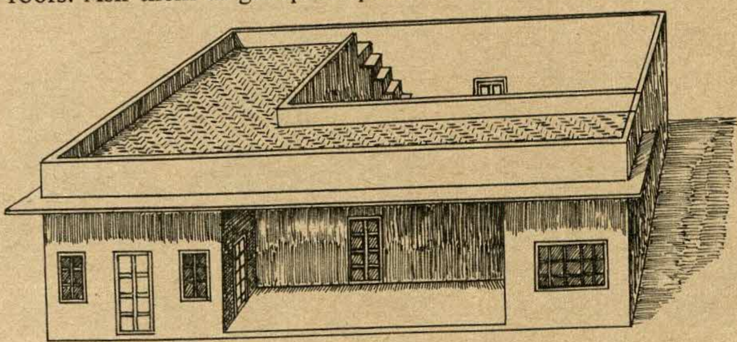


Fig. 6-5a

Fig. 6-5a-c
There are many kinds of roofs for houses.

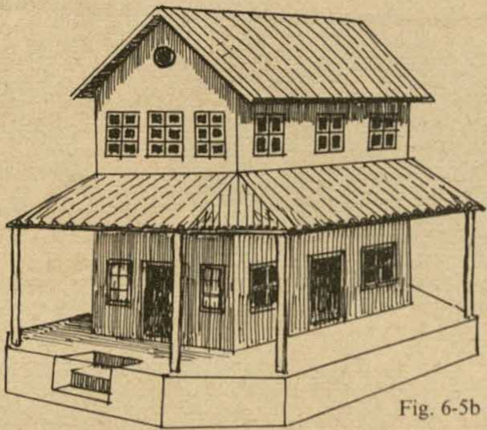


Fig. 6-5b

Fig. 6-5c

Take the children around the village and discuss with them the types of roofs the village houses have.

1(c). ROOFS ARE MADE OF DIFFERENT MATERIALS

On observing the houses in any locality, it will be found that the roofs of houses are made of different materials. Some huts have roofs made of straw, some buildings have roofs made of tinned sheets, some other roofs are made of tiles, while there are still other houses having concrete roofs. The material used for a roof depends upon the climate of the place and the purpose the roof has to serve. The selection of roof material also depends on the financial position of the owner of the house. The idea will be more clear if children do the following activities.

Field Observation

Is there variety in the materials used for roofs?

Let the children to go around in a village or a small town nearby and study the materials used for the roofing of different houses. At the same time, let the children collect for display in the classroom different materials used for making roofs. They may collect straw and bamboo, bricks and

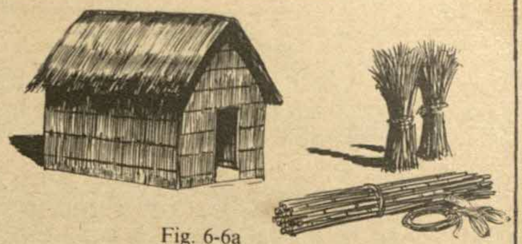


Fig. 6-6a

Fig. 6-6a-c
Many kinds of materials are used to make houses.

wooden planks, a small piece from an iron bar, cement and some stone pieces. The teacher should draw diagrams on the black-board as shown in Fig. 6-6.

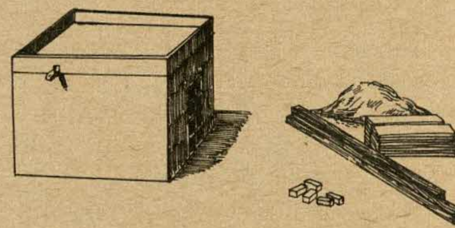


Fig. 6-6b

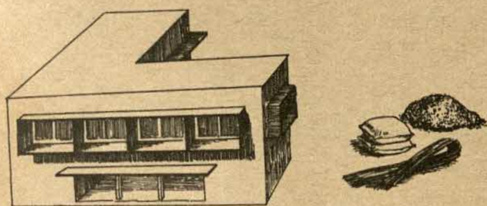


Fig. 6-6c

Discuss with children why rooms with certain type of roofs are cooler than others.

Scientists at Work

Science helps to provide houses for all

Man lives in a family that needs a place to reside. From the earliest times man has been using different types of houses for his residence. As his knowledge about materials advanced he was able to build better and better houses. Thus houses varied with progress in human knowledge. Variety in houses is however not a thing of the past. You can see even now that houses are often very different from one another.

For this, let us take an imaginary trip to northern Canada. It is a very cold place, far in the north. It is covered with snow all the year round. The people that live there are called Eskimos. You will not find familiar brick houses there. The house of an Eskimo may have walls and roofs built of ice. Perhaps there are no windows. You can crawl into the house through a low opening. It is no wonder if you feel rather strange inside the house.

This imaginary trip to Canada shows that houses vary a great deal when climate is very different. Moreover, it shows that houses can be built only with materials that are available in the locality. Eskimos build houses of snow because that is the material easily available for house-building.

But houses are different even when climate is the same. You find this in your own village or city. A rich man can spend more money and, therefore builds a more spacious house. Even

rich men's houses may differ from one another because their owners have different tastes.

Housing is a social problem. All members of a society should have proper houses. The houses may vary in design. They may be big or small. But they should provide shelter, comfort and convenience to the occupants. What can scientists do to help solve this problem? They can develop cheap building materials. They can devise such a cheap method of constructing houses that even the poorer people may have fairly satisfactory houses. How serviceable is science for providing houses to people!

For Better Understanding

A tent is a movable house. It is light and can be carried easily from place to place. The covering is generally made of thick coarse cloth or canvas. The cloth used for the roof is such that the rain-water runs down it easily just as it does on an umbrella. The sides of the tent are covered by flaps of cloth. Some gypsies in this country live in such tents.

There are other movable types of houses such as trailers. A trailer is a small house mounted on wheels. These wheeled houses can either be drawn by hand or towed by a truck or a car. They generally have curved roofs made of some light material such as fabric or aluminium.

Huts, adobe and brick buildings are permanent types of houses. Adobe consists of blocks of clay, mixed with straw to hold the clay together and then baked in the sun. The thick adobe walls keep out the heat of the sun. The adobe houses are commonly found in this country, in Mexico and in South America.

Whatever the type a house may be, it must have a roof. Roofs differ, depending upon the purpose for which they are intended. Flat roofs are generally found in places where there is scanty rainfall.

Where the rainfall is heavy, the houses have sloping roofs. The slope helps water to flow down easily and quickly. In places with heavy snowfall, the slope of the roof is steep. This allows the snow to slide down before it gathers on the roof and breaks it. When the roof has to be light and yet strong, curved roofs are often used.

Roofs are made of different covering materials. In the south, and along the coast where the coconut trees abound, the roof may be made of dry palm leaves. For go-downs and temporary hutments, tin roofs are used. The tin sheets are generally corrugated. They are not smooth and flat; they have a wave-like surface. This gives them strength. Nowadays, many houses have concrete roofs. The old buildings and houses in villages have roofs made of tiles. Tiles are cheaper, but they are fragile. Most of the farm labourers and villagers live in huts which have roofs made of straw.

India is a vast country. We are still in the developmental stage. Housing is a problem for many in our country. This problem needs tackling in two different directions. On the one hand, there is quite a number of people without houses to live in. Communities must provide a minimum housing

accommodation to these pavement dwellers. On the other hand, there are many families throughout the country living in slums. Better houses should be provided for them. Rapid industrial development has resulted in unchecked growth of cities through transfer of population from rural areas. A planned development is, therefore, necessary in this direction also.

UNIT 6

HOUSING AND CLOTHING

CLASS III

Overview

In classes I and II of this unit children have seen that a house provides shelter and comfort. They have also observed that houses are often very different from one another. The teacher can help children to investigate these points further in this class.

The children are now a bit more mature. They can see not only that houses provide shelter and comfort, but also that some houses provide it better than others. That is, there is great *variety* in the usefulness of houses.

A discussion of why the houses are of different types is not the primary concern of the teacher at the class III level. It is enough if they can analyse how houses offer convenience and comfort, and how they provide safety. It is through such inquiries that the teacher can help children to conclude that a house is meant for security and comfort.

As far as possible the teacher should play down the economic reasons for variety in houses. Even among families of the same financial status, some have better planned houses than others. This concept of planning is an important idea of this unit at class III level.

The children know the functions of a house. Through *observations,* followed by *discussion,* the teacher can help them discover how houses fulfil these functions.

1. A HOUSE SHOULD OFFER CONVENIENCE AND COMFORT

People, in general, select such houses to live in as can offer maximum convenience and comfort within the means available. For example, in big cities, a house will be preferred in such a locality where conveyance in the form of bus, taxi or any other transport is easily available within a short distance from the house. This may not be a worthwhile consideration if the house is in a small town. In short, a house should be located where there are facilities for a good market, a good school, a good hospital, and other such services.

Conditions of convenience and comfort are closely related to the habits of the family members. The absence of electric supply and appliances may not be a discomfort to a village family. But to a city dweller, these facilities may appear as a necessity. Selection of a house is thus a compromise in many ways.

In addition, the structure of the house

should be such as to make it a comfortable place to live. Every room should have an access to another room so that one can move easily without disturbing the household.

1(a). A HOUSE SHOULD PROVIDE SPACE FOR EATING, SLEEPING, STUDYING, BATHING, WASHING AND STORAGE

It is not hygienic to cook the food, wash the clothes, bathe, and dine in one and the same room. It is neither comfortable nor convenient to sleep in the same room where the food is cooked or clothes are washed.

For convenience, comfort and hygiene there should be separate rooms for eating, sleeping, and general living. If possible there should be a separate room for cooking. The children will understand this better if they are invited to the following types of activities.

Discussion | **What makes a home convenient for me?**

Ask the children to report on the house they live in. Does it have a kitchen, a dining-room and a bathroom besides one or more living-rooms? Is it convenient to move from one room to another? If so, can they do it without disturbing others in the house? Where do the members of the family sleep? Where do the children sleep? Then ask them to discuss whether the house they live in is comfortable and convenient.

Discuss with the class what should be done when the family budget requires that there should be a house of one or two rooms only.

Could some functions like cooking, eating, sleeping, studying, bathing, washing and storage be carried out in a common place? What will be the criteria of bracketing together some of these activities?

1(b). THERE SHOULD BE AN OPEN PLACE FOR OUTDOOR ACTIVITIES

In a family where there are children, it is necessary to have a place away from the house or the living-rooms—a place where they can play without coming in the way of others and without damaging the furniture in the house. A house should therefore have a courtyard or a garden. The courtyard will then serve as a place for children to play. For other members of the family the courtyard will serve as an open place for relaxing during summer evenings. A big broad veranda is also suitable for the above purpose. Help children to understand this sub-concept well through the following kinds of activities.

Discussion

Why is an open courtyard desirable in a house?

Discuss with children if there are courtyards in the houses where they live. Ask them where they play during the summer vacations. Where do various members of the family sleep in summer? Where does the family sit on summer evenings? Is there enough space in and around the house where the child can run about and play football, hockey or cricket? Let the children answer to each one of the above questions. The teacher can now help them conclude that an open courtyard is desirable in a house.

What is an open space necessary for playing (a) from the point of view of children's health, (b) for safety of household articles?

In cities, new colonies are often developed by constructing houses around sides of a rectangular field. Discuss with children why it is so. (The houses are small and do not have courtyards. The field serves as a common courtyard.)

1(c). THE HOUSE SHOULD GIVE PROTECTION FROM HEAT, COLD AND RAIN

When a house is being built, one should bear in mind that the purpose of the house is to protect people from the heat of the summer and the cold of the winter. The house should protect from rain-water during the monsoons.

The heat can be warded off by constructing thick walls and high ceilings. Thick walls keep out the cold too; a good roof with proper outlet for rain-water can protect the people in the house from the rain. To understand the sub-concept well, let the children carry out the following activities.

Discussion

How does my house protect me from heat, cold, and rain?

Ask each child to give an oral account of the structure of the house in which he lives. Help the child to discuss the structural features of the house, such as walls, roofs, windows and doors, in relation to the different kinds of protection they provide.

From the earlier times man was forced by the unfarvourable conditions of weather to seek a place to hide himself. Encourage

children to discuss which among the following were the most influential factors for creating this need: extreme heat, severe cold, heavy rains, or others.

2. A HOUSE SHOULD OFFER SAFETY AND SANITATION

Every person considers a house to be a safe place. This is so because the doors, windows and the walls offer protection from robbers and other enemies. To make the house safe to live in, the doors and windows should be such that they can be securely bolted and locked.

Robbers and thieves are not alone in being dangerous to human lives. Diseases can be even more dangerous. Just as a house should provide safety against robbers and other enemies, it should also provide safety against diseases. Sanitation is the method of keeping diseases away.

Of the three sub-concepts discussed here the first two are related to safety and the third to sanitation.

2(a). DOORS AND WINDOWS SHOULD HAVE PROPER BOLTS AND BARS

The children already know that the safe place for them is the house. They also know that they feel safe when the doors and windows are barred. To bring out such knowledge, the children may be questioned thus.

Discussion

How do we protect ourselves from thieves?

Ask the children to examine the doors and windows of the house where they live. What precautions are taken against enemies and thieves? Notice the type of bolts and latches. They may be invited to observe how the doors are locked: (i) from the inside of the room, (ii) from the outside.

Help children to compare older types of bolts and bars with the newer ones.

2(b). DOORS, WINDOWS AND ALMIRAHS SHOULD BE CLOSED TIGHTLY

It is common knowledge that doors and windows which do not close tightly can be easily broken. Moreover the openings serve as an entrance for rats. To safeguard against this, the doors and windows should be tight-fitting when closed. Almirahs, too, should have tight-fitting doors so that rats and insects may not enter. With tightly closed and firmly locked cupboards, it becomes difficult for a thief to make away with things.

This understanding may be developed through the following type of activities.

Discussion

How do we prevent the entrance of thieves through doors and windows?

Invite children for a discussion. Ask them where they and their parents keep precious things? If the doors of the cupboard or almirah were not so tightly closed, would it make any difference as far as protection against rats and insects is concerned? Why are tight-fitting doors and windows necessary?

Puzzle

A certain poorly-fitting door is closed on the inner side with a special type of latch. It can be opened from the outside by a child, but not by his father. Encourage children to suggest a plausible reason. (The child's slender arm can pass through the opening to reach the latch; his father's large arm cannot.)

2(c). THERE SHOULD BE ADEQUATE DRAINAGE OF KITCHEN AND BATH-ROOM WATER

Every household uses water for washing and cleaning. The water thus used becomes dirty. For the maintenance of good health it is necessary that this dirty waste water is removed safely from the house. To do this effectively there should be covered drains. The most common method is to dig a drain from the kitchen water tap and allow the water to flow into a main drain or sewer. In big cities pipes are used for carrying the waste water. The city's sewage pipes are laid underground. The children can be invited to carry out the following activities to assimilate the above ideas.

Investigation

How is drain water disposed of in my locality?

Let children observe where the dirty water from the kitchen and bath-room goes. Let them also observe the removal of waste water in a few other houses in the neighbourhood and compare what they find with their own disposal method. Ask them to report about their experiences. See Fig. 6-7.

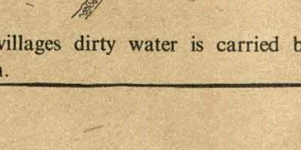


Fig. 6-7
In some villages dirty water is carried by an open drain.

In places where there are open drains as well as closed drains and pipes, the children may be asked to compare the different methods of drainage and to state which is better. If possible the children may be shown the village cesspool.

A visit may be arranged to a sewage disposal plant near the locality.

For Better Understanding

Wherever people live, they need water to drink, to wash and to clean. In the process of washing and cleaning, the water becomes dirty. This dirty water is sometimes allowed to collect on the floor of the house or around it. Such a collection of dirty water makes a good breeding ground for mosquitoes and germs. Germs are the cause of most diseases. Hence, it is very necessary that waste or dirty water is disposed off very quickly and effectively.

There are many ways of disposing of dirty water. In villages small drains are dug leading away from the house or the kitchen or bathing place. But these drains are usually open drains, and carry the waste water to a ditch near the house. This is not sanitary. For good hygiene, the waste water should flow into a deep hole covered on the top. Instead of open drains, closed drains are better. Even better than the closed drains are the glazed earthen pipes. In most of the big cities the waste is carried through glazed earthen pipes. These pipes empty their waste contents into the city's main drainage system. The main sewage pipes carry the waste to a river or an ocean, or to a sewage disposal plant.

Scientists at Work

Clean housing promotes good health

Today let us talk about the 'science of cleanliness'. You may wonder how cleanliness could be a science. It is so much a part of religious practice.

True, cleanliness has been a religious practice for a long time. We can guess why it came to be regarded as a part of religion in the beginning. Many people over long periods observed that persons with habits of cleanliness were healthy and happy. Religious persons might have thought that these people are happy because they are having God's favour. Furthermore, the wise leaders of the group knew that they could get the others to practise cleanliness if they made it a part of religious ritual. Thus cleanliness may have become associated with religion.

Now, of course, we know that dirt and disease are closely related. Though the archaeological remains of some ancient cities show that their inhabitants had a sense of public sanitation,

probably they did not know that dirt is one of the causes of disease. One of the pioneers who brought sanitary awakening in America was William Thomson Sedgwick. His book *The Principles of Sanitary Science and Public Health* helped people to understand the importance of keeping clean for maintaining health. There were other scientists in many other countries trying to make people conscious of sanitation.

Many diseases are caused by the entrance of germs into the human body. Louis Pasteur, the famous French chemist, is known as the father of the germ theory of disease. He was working on some industrial problems, such as 'wine turning into vinegar' and the silk industry facing extinction because of the large-scale death of silkworms. While doing this he got the vital idea that specific germs cause specific diseases. Germs are very minute living things, so small that they are not visible to the naked eye. Germs multiply very rapidly. Even if they enter a human body in small numbers, they soon multiply into millions. Thus the human body gets a disease corresponding to the germs that have entered. At first the number of germs is small, and the body easily resists their action. A healthy body often does this successfully if the infection is not serious.

Germs are almost everywhere. At some places, they are very abundant and extremely dangerous. Filth is dangerous because it carries germs from one place to another.

How do germs enter our body? It is done mostly through food and drink. If these are kept exposed, dust laden with germs settles on them. Once inside our body with the food articles, germs begin to multiply, making us fall ill. Germs are killed by heating. During the cooking of food most germs are killed. Food thus prepared should not be carelessly exposed to dirty air or unclean places.

Cleanliness works both on the personal and on the community level. One may, however, argue that avoidance of personal filth is more necessary than cleanliness of streets and lanes. Yet it is easy to see that if the street drains are dirty and exposed, they will be powerful sources of infection for all that pass that way.

How intimately our health and happiness are associated with the people around us!

UNIT 6

HOUSING AND CLOTHING

CLASS IV

Overview

The content of this unit at class IV level is different from those at other class levels. One special feature is the sub-unit, 'Clothing' Major concepts under the title 'Housing' are discussed at all class levels from I through V. Discussion of concepts under the 'Clothing' aspect of living is a special feature of this class only.

Two major concepts are discussed under 'Housing'. One relates to conditions of proper sanitation and healthful living. The other deals with the various materials that can be used for constructing walls, roofs, and floors. But this discussion of variety in design and outer form of houses and roofs has been done in previous classes as well. The unit here is different in being more involved with actual living conditions. The teacher can help children see that a house is to be judged, not only on the basis of its design or appearance but also on the conditions it affords for living.

At class IV level an approach is made to such questions as:

Does the design of the house provide for enough sunlight and for free movement of air? Is it sufficiently free from dust and dirt? Do the floors dry up easily? Such knowledge will be of great help in the selection of a proper house-design and of suitable materials. The teacher can help children discuss the variety of materials used in building houses in the light of sanitary conditions they provide to a house.

The sub-unit 'Clothing' has five major concepts. The first discusses clothing as a need—both physical and social. Clothing protects people from the sun and also helps one look and feel decent. The second and third major concepts deal with variety in clothing. It is a common experience for children that clothes in summer differ from clothes in winter. The teacher may relate the variety in clothing to a somewhat similar variety in houses with respect to climatic conditions. Just as different materials can be used for housing, different materials can also be used for preparing clothes. The fourth and fifth major concepts discuss the production and care of clothing. During the discussion of production, the teacher can guide children to visualize how other people are working for meeting their needs. The interdependence between different sections of society fits in well with this unit. The fifth major concept, 'Clothes last longer when well cared for', gives some much needed information about the care of one's clothes.

Housing

1. CLEAN, TIDY, WELL AIRED AND SANITARY HOUSES ARE HEALTHY

The house in which one lives determines to some degree the state of one's health. This is true for all places and all climates.

A house should protect a person living in it from extremes of heat and cold, moisture and dryness. It should be free from insects and vermin. It should provide for an adequate supply of light and air. Air, in and around it, should be free from poisonous or offensive-smelling gases and dust. There should be no accumulation of water on floors and near the house. Windows should have wire nettings so that mosquitoes and flies cannot enter the house.

1(a). A HOUSE SHOULD HAVE FREE MOVEMENT OF AIR

A house should be so constructed that fresh air enters each room. The site where the house is built should be such as to allow free movement of air unobstructed by tall structures nearby.

In order to make a room airy, windows and doors should be facing east-west, to take advantage of the most common winds. It is common practice to construct openings high up on the walls near the ceiling. These openings are usually guarded by a movable window-type of structure, hinged to the centre of the opening. Such an opening is called a *ventilator*. A ventilator allows the air to circulate due to natural draughts and can be left open when doors and windows are closed.

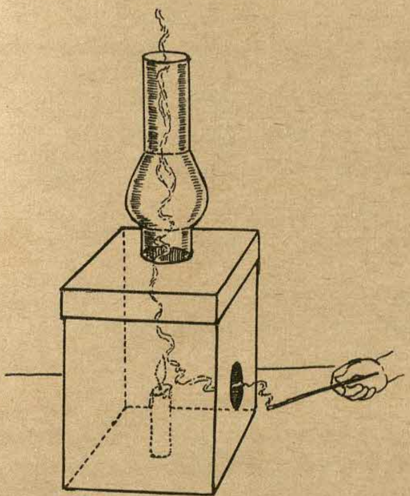
The keeping of doors and windows opposite to one another allows fresh air to enter from one side and impure air to be pushed out from the other. The children can be helped to understand about the free movement of air through the following activities.

Demonstration

How does ventilation help in the free movement of air within a room?

Materials required
cardboard box
candle
match-box
agarbatti (incense)
lamp chimney

Prepare a cardboard box about 30 cm high and about 15 or 20 cm on each side. The top of the box should be detachable. Cut two holes (1 cm diameter—one at the top and the other at one end, as shown in Fig. 6-8. Place a lamp chimney above the hole 'A'. Fix a small candle inside the box at the centre of the bottom. Light the candle. Replace the lid. Hold a smouldering *agarbatti,* near the hole 'B'. The children will observe that smoke enters the box through the hole 'B' and gets out through 'A', up through the chimney. Help children in understanding how a draught of air is produced in this model. Hot air above the burning candle rises because it is light. Cool air from outside comes into the box through the hole 'B' to occupy the space left by hot air. Help children in understanding that a similar situation develops in a house. Warm air, breathed out by persons living in a room, rises towards the roof and leaves



the room through the ventilator. Cool and fresh air enters the room through the doors and windows to fill up the partial vacuum.

Fig. 6-8
This simple ventilation box illustrates one way in which air circulates in a room.

Repeat the above investigation with a cardboard box having one hole at the centre of the top. Divide the hole into two halves by putting a T-shaped strip into it as shown in Fig. 6-9. Hold an *agarbatti* over one half. The smoke comes out through the other half. A draught is thus produced with a single hole. Draw diagrams of ventilators as shown in the sketch. Discuss how draughts can be produced even with single openings by the help of such ventilators.

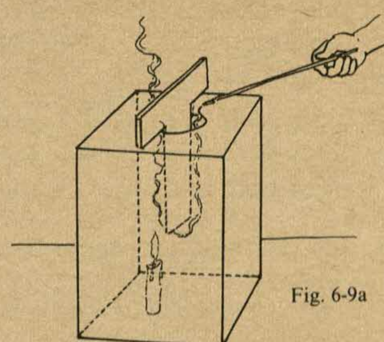


Fig. 6-9a

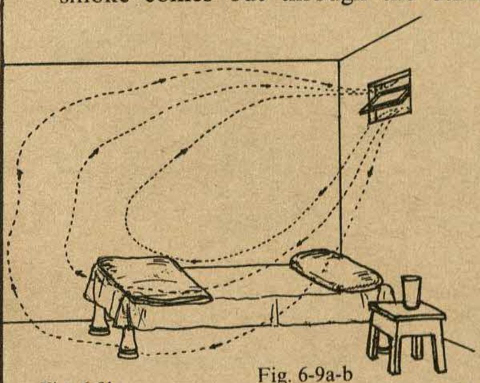


Fig. 6-9b

Fig. 6-9a-b
A properly constructed ventilator permits cool air to enter, to be warmed by the living space, and to leave.

Discuss with children how cross-ventilation is provided by having doors, windows and ventilators on opposite walls. Discuss how this helps in making the room airy. For example, when wind is blowing through the doors ask the children to shut the doors and windows on the opposite side of the classroom. Does the wind still blow through the room?

Ask the children why doors and windows are often kept closed in winter. What difference would it make if they were kept open in winter.

1(b). A HOUSE SHOULD HAVE ADEQUATE SUNLIGHT

Sunlight is one of the most effective germ killer. It is on this account that living rooms should be so placed as to have an entry of sufficient sunlight during the day. This can be assured by having doors and windows facing either east or west. This allows the sun's rays to come into the room when the windows or doors are open. Children will understand the effect of sunlight in preventing the growth of germs through the following activities.

Investigation

Does moist bread keep better in the sun or in the dark?

Materials required
2 pieces of bread
2 plates

Moisten two pieces of bread and keep one each on two different plates. Place one plate in the sun (throughout the day) and the other in a dark, damp place. Invite children to observe the plates on the third day. Children will observe as in Fig. 6-10 that some dark, greenish substance (bread mould, a simple plant) has grown on the bread that has been kept in the dark. Help children understand that in a similar way germs multiply very rapidly in the dark. Sunshine prevents the growth of germs and often kill them.

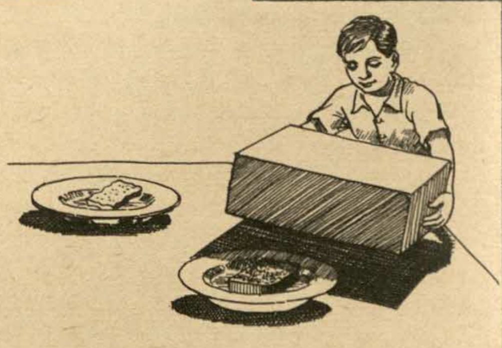


Fig. 6-10
Mould sometimes grows on damp bread.

Discuss with children how clothes lose their 'musty' odour and smell fresh when they have been dried in bright sunlight.

1(c). A HOUSE SHOULD BE KEPT FREE FROM DUST AND DIRT

It is known that dust and dirt are carriers of disease germs. Dust by itself is not harmful. Furthermore, it is prevented from entering the lungs by the fine hairs and mucous in the nose. However, dust and dirt carry germs. Therefore, it is important that there should be no excessive dust or dirt in a home. The house should be swept and washed daily. The dust and dirt should be collected and put into a dust-bin for disposal.

Trees and plants and grass keep away the dust. However, it is best to have a house well away from heavy traffic and from muddy fields and roads. No one can avoid dust completely. Everywhere there are fine particles of dust in the air. Remind the children that in spite of closing the doors and windows of the house, the furniture and other objects in the house are covered with dust.

The children can comprehend this sub-concept better through the following activities.

Field Observation

What conditions reduce accumulation of dust in houses?

Let the children visit some houses which are near the road and some houses which are surrounded by gardens and greenery and are therefore away from the road. Encourage the children to observe which of the houses have more dust on them and to discuss how the dust could be reduced.

Invite the class to discuss why there are more flies in one place than in the other. Help them conclude that filth attracts flies.

1(d). FLOORS SHOULD BE EASY TO DRY

Wherever water accumulates, germs and mosquitoes are likely to grow. For this reason precautions must be taken that the floor is so constructed that the water dries up easily or drains off quickly. The floor of the house, therefore, should be solid and hard and there should be no ruts or pits on the floor. Presence of water, even as moisture, is harmful, for it makes the room damp and the air in the room humid. Dampness and warmth are favourable to the growth of germs. To bring home to the children the necessity of a good, hard, smooth and dry flooring, encourage them to carry on the following activities.

Discussion

Which type of floors usually remain damp?

Put the problem 'Which type of floors usually remain damp?' as an assignment for discussion during the next week. Encourage students to observe

the different floors they see during this period, and to write a remark about their comparative dryness. Through discussion of such data children will be helped to see that the floors remain damp when (i) there are pits on the floor, (ii) the material of the floor is porous and absorbs water instead of allowing it to drain out. Children will also observe that they can keep the floors dry by being more careful about the use of water.

Urge children to ask their parents how it is possible to provide a floor which is inexpensive yet dry.

1(e). WINDOWS SHOULD HAVE WIRE NETTING

Wire nets on windows prevent flies from entering the rooms. Other insects, too, are effectively kept out of the rooms. This precaution is more necessary during the rainy season. Small insects come in during the night when the lights are on. Through the following activities help children understand that netting keeps the flies out.

Teacher Demonstration

How do nets keep flies away?

Materials required
two plates with sweets
a netting cover

Invite the children to keep some sweets in two plates, one covered by a net and the other without a net covering. Ask them to watch on which plate there are more flies. They will find, as shown in Fig. 6-11 that the net prevents flies from reaching the sweets.

Fig. 6-11
Nets keep flies away from eatables.

Discuss with children other ways of keeping away flies. How are nettings better in this respect?

2. A VARIETY OF MATERIAL IS USED IN BUILDING HOUSES

The building of a house is a big job. It involves the labour of many persons skilled in their trades. Construction of a good house, therefore, needs not only many skilled tradesmen, but also many types of materials. Each material is chosen because of its particular properties.

Walls, which need to be strong and solid,

are made of bricks, mud or wood. Roofs, which are meant to protect a person living in a house from sun and rain, are generally made of damp-proof and heat-insulating material. Many modern houses are made from concrete and brick. Iron and asbestos-corrugated sheets are often used in the construction of roofs because they are cheap and are good damp-proof materials. Similarly, tiles are used in the construction of roofs and floors because they are fire-proof and damp-proof. Thatch, used for roof-making, is a good insulating material. It keeps away the heat of the sun effectively. However, it holds dampness and dirt, and is also a fire hazard.

Floors which need to be kept clean and dry are generally made of stones, bricks, or concrete. Walls are often plastered to help them remain clean and dry.

2(a). WALLS ARE MADE OF BRICKS, MUD OR WOOD

Depending upon the cost and the purpose of the house, its walls may be made of brick, mud or wood. Bricks are used for putting up a strong building. Nowadays walls of houses are generally made of bricks. In villages, most houses are made of sun-dried mud-bricks, while some are made of wood. Invite children to carry out the following activities to help them have a better appreciation of the idea that walls can be made of different materials.

Field Observation

What common materials are used for constructing walls?

Invite children on a trip of a house-building site. Show them how the walls are being raised. Discuss with them the functions of materials being used for erecting the walls, e.g., the bricks are for support and the mud or plaster serves as a binding material.

Discuss with children how tin sheets and wooden structures are sometimes used as partition walls. What is the special advantage of these structures? (They occupy less space.)

2(b). ROOFS ARE MADE OF CONCRETE, TILES, CORRUGATED METAL, ASBESTOS, OR THATCH

Roofs are meant to keep away the sun's heat and rain. Many different kinds of materials are used. Many modern houses have flat roofs made of concrete. Concrete is both water-proof and heat resistant. It is also strong and durable. A few of the houses in a village may have asbestos-corrugated roofs. But, by and large, the roofs of the huts or houses are made of thatch. Straw or dried palm leaves make good light roofs. However, they have to be re-made every year before the monsoon. Straw, being a good insulating material, keeps the rooms cool even in summer. The children will understand better that roofs may be made of different materials through the following activities.

Field Observation

What materials are needed for making roofs?

Invite children to visit a house being constructed. It should be so arranged that children can see and discuss the materials used for constructing the roof.

Ask children to discuss with their parents what other materials can be used for roof-making.

The children may be asked to collect samples of the different materials used in roof-making and bring them for display in the classroom.

2(c). FLOORS ARE MADE OF BRICKS, CEMENT, OR STONES

Since floors have to be washed and cleaned by using water, it is very necessary that the floor covering should be of a material which is quick-drying and damp-proof. In villages, there can still be found huts with mud flooring and with cowdung spread on it. This kind of flooring is cheap but needs to be maintained regularly. A concrete floor is the best type. In towns and cities the floors of rooms are made of concrete or concrete mixed with marble chips. There are some old buildings which have floors made of bricks or stones. These types of floors are not good from the sanitary point of view because water collects in the small pits of brick, or stone flooring. The children will develop greater interest in this topic by the following activity.

Class Project

How do the floors in our houses compare with those of others?

Let the children find out what type of floor their houses have and how it compares with their neighbours' floors. They may inquire or investigate if any house in the locality has brick or stone floors. Help them to discuss which floors are better. What are the reasons?

2(d). PLASTERING HELPS TO KEEP WALLS CLEAN AND DRY

In order to keep the walls of the room dry, damp-resisting material is used. The most common such material is plaster. Plaster consists of a mixture of lime, sand, cement and water. This sub-concept will be better understood if children are encouraged to do the following activities.

Class Project

How does plastering keep a surface dry?

Materials required
bricks
sand
lime
cement

Procure some lime, sand and cement. Prepare three plasters by mixing (i) lime, sand and water, (ii) cement, sand and water, (iii) lime, cement, sand and water. Help children to apply these plasters to different bricks. Let the bricks dry up. Invite children to observe which plaster has set the best way. Put these bricks in water for some time. Take them out and wipe off the excess water. Help the children find out which of the plastered bricks dries out most quickly.

Ask children to discuss with their parents what other types of materials can be used for plastering walls.

Ask children to clean a wall which is plastered and one which is not. Which one is easier to keep clean, dry and sanitary?

For Better Understanding

The floors and walls of houses are covered with many materials. Concrete is very commonly used nowadays. Concrete is made by mixing cement, sand, gravel and water. Cement binds the ingredients together. Cement itself is a mixture of limestone and clay, baked until it forms a hard mass. The mass is then ground into fine powder. This cement powder is then properly mixed with lime, sand, and water to make the plaster. After the fresh cement plaster has dried a bit, it should be kept moist with water for about a week. This helps in the 'setting' of the cement plaster.

Clothing

3. CLOTHES GIVE PROTECTION TO MAN AND IMPROVE HIS APPEARANCE

Clothing is necessary for modern living. Clothes help the body to adjust to the changes in weather and climate. Clothes protect one from heat, cold and rain. The kind of clothing one wears depends to a very large extent upon the seasons, and also upon the climate in which one lives. Clothes also help to enhance one's appearance and smartness.

3(a). CLOTHES PROTECT THE BODY FROM SUN, RAIN, DUST AND INSECT BITES

Clothes are worn to protect the body from

excessive heat during summer and from cold in winter. Certain types of clothes are used to protect from the rain. Clothes also protect the body from dust, and safeguard it against insect bites. In order that the children may understand the utility of clothes, the following activities may be performed.

Discussion — **What is the utility of clothes?**

Discuss with children the following questions: What kind of clothes are you wearing now? Are they made of cotton or of wool? Could you do without clothes in winter? What kind of clothes do you wear in winter? Why? Would you wear the same type of clothes in summer? Why? How would you feel during the summer if you stand in the scorching heat of the sun without clothes?

Let the students observe the exposed and unexposed parts of the arm. Discuss why there is a difference of colour? Through such questions, help children in understanding that clothes give protection from sun, rain, dust and insect bites.

The children may be asked to collect different types of pieces of clothes and label them as cotton, woollen, silk, etc.

Sometimes we cannot sleep because of mosquitoes. Discuss how mosquito-nets or cloth sheets can help us in this matter.

3(b). NEAT AND TIDY CLOTHES MAKE US LOOK ATTRACTIVE

It is a common fact that good clothes make one look attractive. A person dresses in his best clothes when he wishes to create a good impression on others. To make the children appreciate that good clothes make a person more attractive, encourage them to do the following activity.

Discussion — **Do clean clothes make us look better?**

Ask the children to compare dirtily-clothed children in the streets with the children in the class. Ask who looks better and why. Let them discuss how appearance depends on the type of clothes one wears.

4. DIFFERENT KINDS OF CLOTHES ARE USED IN DIFFERENT SEASONS AND CLIMATES

Civilized people all over the world wear clothes, but the type of clothes they wear

vary from place to place and from season to season.

People in very hot countries sometimes wear very little clothing. This is because the heat is often so oppressive that they feel better without clothes. The clothes that are worn get wet with perspiration and have a foul odour. In some parts of South India and in the regions of Central Africa, and in many other hot countries people wear clothes just to cover their loins. The loin cloth is made of cotton and is very light and thin. The upper half of the body is left bare.

People living in extreme cold, like that of the Arctic regions, wear thick woollen clothes or clothes made out of the skin and fur of animals. Leather is a material which the wind cannot easily penetrate. It is thus easy to understand why gloves are made of leather. Sometimes fur is reversed for wearing in bitter cold, so that the hair is inside. Air cannot circulate in the closed spaces created by the overlapping of hairs in the fur. When air cannot circulate it provides protection against the loss of heat, and hence helps to retain the heat of the body. This is because air is a poor conductor of heat.

In cold places like Europe, people wear clothes made of wool, while in warm countries people generally wear light cotton clothes.

4(a). COTTON CLOTHES ARE WORN IN SUMMER AND WOOLLEN CLOTHES ARE WORN IN WINTER

Man chooses clothes which will keep him warm in cold weather and cool in warm weather, and dry in wet weather. Fur, wool and leather are used to keep the body warm. In summer loose-fitting and light cotton clothes keep the body cool. Certain clothing materials help in retaining the heat of the body, while other materials allow the heat of the body to escape. Invite children to the following activities to understand the above ideas.

Discussion

Why are our summer clothes different from winter clothes?

Have a discussion with children on the following lines: Why do you wear clothes? What kind of clothes are you wearing now? Would you wear the same type of clothes throughout the year? If not, why not? What is the reason for wearing woollen clothes in winter? Would you wear woollen clothes in summer also? If not, why? What kind of clothes do you wear in summer?

When you have satisfactory answers to the above questions, help the children realize that people wear light cotton clothes in summer, and heavy woollen clothes in winter.

Children may be asked to collect various types of cloth from which dresses are made. Let them classify the material under two heads: (a) for summer dress, (b) for winter dress. Compare the types in respect of softness, smoothness, roughness and lightness.

Discuss with children why khadi is a good wear for summer. It protects people from loo*—the hot wind—and absorbs the sweat from the body.*

4(b). CERTAIN CLOTHING MATERIALS ABSORB THE SWEAT FROM THE BODY IN SUMMER

Soft cotton clothes like vests are worn next to the skin in summer because they have the property of absorbing sweat. The material is of a special type, and is woven in a special way. Its texture is such that the skin does not feel irritated in contact with it. To make the children understand this sub-concept invite them to do the following activities.

Investigation

Which clothing material absorbs moisture most readily?

Materials required
cloths of different types
tumblers

Ask the children to obtain samples of different types of fabric, and let them cut sample strips of equal size. Ask them to pour water into tumblers of the same size up to the same height. Let each piece of cloth be dipped separately into the water in these tumblers for a minute as shown in Fig. 6-12. Then the pieces of cloth are lifted carefully allowing the excess of water to drip back into the tumbler. Hang each cloth on a rope for drying. Let the children find out how much water each sample soaks up and how much time each sample takes for drying.

Fig. 6-12
Some kinds of cloth absorb moisture very readily

They will discover that some types of cloth are better absorbers of moisture than others.

How does the material of undershirts and socks differ from that of shirts or pants? Discuss with children which factor they would regard as the most important in the selection of a ready-made garment: price, colour, material or fitting.

For Better Understanding

The nature of the fabric is a very important factor in choosing the cloth for one's dress. Woollen cloth is one of the warmest fabrics. Air spaces between the fibres of the woollen

fabric are such that air cannot circulate easily through them. For the summer, loose open weaves are desirable since comfort depends upon the air circulating freely through the garment. This allows the perspiration to evaporate faster. The quicker the evaporation of the perspiration, the cooler one feels.

Fitting is still another factor in keeping comfortable. However, some people like tight-fitting and others like loose-fitting clothes. In winter woollen cloth around the neck will prevent the escape of heat. A small layer of trapped air helps the body conserve heat. The weight of the fabric is also to be taken into account in choosing clothing material. The heavier the fabric, the more layers of fibre there are. This increases the number of dead air spaces and thus prevents the body heat from escaping. Colour too plays an important part in the selection of clothes. Dark-coloured fabrics absorb radiant heat and quickly become hot. But white clothes absorb less heat, since most of the heat rays falling upon them are reflected back. It is for this reason that people often wear white cotton clothes in summer.

5. THREAD AND YARN ARE MADE FROM NATURAL OR ARTIFICIAL FIBRES

Cloth is made by weaving thread or yarn. Thread is prepared by spinning fibres of cotton, linen, wool or silk into long strands or strings. Fibres are hair-like fine structures from plants, animals and also from artificial sources.

Fibres are thus the raw materials for manufacturing any cloth. Some fibres are obtained from natural sources. For example, the cotton plant provides cotton which is a fibrous material. Fibres of cotton are spun into cotton yarn and then woven into cotton cloth. The fibrous material for linen cloth is obtained from the flax plant. Wool and silk fibres are obtained from animals. Nowadays a large quantity of cloth is prepared from many kinds of artificially prepared fibres such as rayon, nylon, decron and terylene. Fibres of glass and of asbestos and of metal can also be spun into threads and woven into cloth. The sub-concepts which follow are intended to help students learn more about the preparation of fabrics.

5(a). COTTON AND LINEN ARE OBTAINED FROM PLANTS

Cotton is the most common fibrous material used for the manufacture of cloth in India and other tropical countries. Cotton fibres are found on the fruits of the cotton plant. They are soft and fluffy. Another common plant fibre is linen which comes from the flax plant. This fibre is long, lustrous and smooth. Linen has good water absorbent qualities. It is, therefore, used to make handkerchiefs, table-cloths, napkins, and summer dresses. The children will understand this better by participating in the following activities.

Investigation

How does raw cotton differ from cotton thread?

Materials required
cotton thread
raw cotton
wool

Ask the children to collect some raw cotton (*rui*) and feel its hair-like structure. Let them compare it with a cotton

thread. Encourage them to observe the difference between the spun fibre and the raw cotton, as shown in Fig. 6-13. Compare wool fibre with cotton fibres.

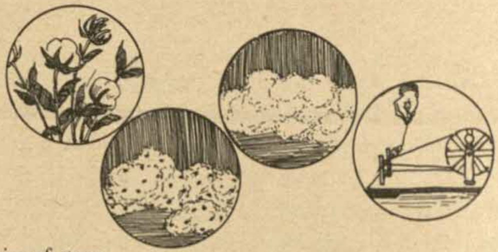


Fig. 6-13
Cotton fibres are made through a series of steps.

Show raw cotton bales to children and discuss how cotton fibres are separated from seeds before spinning.

Show a linen cloth to children and help them compare it with a cotton cloth.

5(b). SILK IS OBTAINED FROM THE SILKWORM

Silk is obtained from the outer walls of cases (called cocoons) that the larvae of some moths weave around themselves. Though the adult moth is an insect, its larva (often called a caterpillar) looks like a worm. Hence it has been named silkworm.

Silkworms are not common. However, moths are found everywhere. Some of these common moth larvae make cocoons. Though silk cannot be obtained from these cocoons, the children can at least understand through activities of the type suggested below, how a larva prepares a cocoon.

Investigation

How are cocoons formed by larvae?

Materials required
moth larva
twigs
leaves
shoe-box
cellophane

Fig. 6-14a, b
Silk worms change, construct coccoons, then change to adult insects.

Make a transparent window in a shoe-box by replacing part of its wall with cellophane. Put a caterpillar (larva of a moth or butterfly) inside this box, along with the twigs and leaves of the plant on which it is found, as shown in Fig. 6-14. Invite children to observe it periodically for about three weeks. They will observe that the larva is at first very active in eating leaves, etc.

After about a fortnight the larva starts spinning the cocoon. Then it remains inactive inside the cocoon. After some days the adult insect comes out of the cocoon as a completely changed animal.

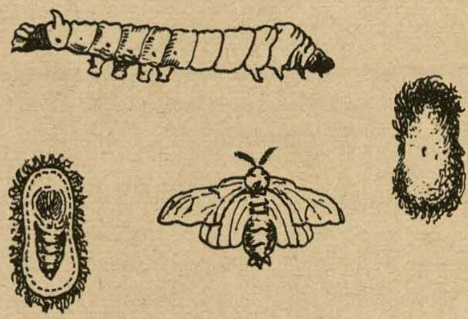


Fig-14b

Ask children to discuss with their parents which is better for making cloth—natural silk (from the silkworm) or artificial silk and other synthetic fibres.

For Better Understanding

'Silkworm' is the name applied to any caterpillar that spins a cocoon of silky fibres which may be used for producing silk-cloth. The mulberry silkworm (*Bombyx mori*) is a common variety. It is the larva of a moth with a short thick body, stout legs, and broad wings.

The female moth lays about 200-500 eggs, each about the size of a pin-head. The eggs are collected and kept at about 10°C in a dry, airy atmosphere. In spring, the temperature is raised to about 23°C. In about 10 days larvae emerge from the eggs. These larvae are then covered with sheets of perforated paper, over which are sprinkled chopped mulberry leaves.

The young larva is about a half centimetre long. It eats about its own weight of leaves daily. Hence, the mulberry leaves are sprinkled over it several times during the day. The larva continues to grow for about six weeks when it becomes about 8 cm long. During this period it changes its skin four times. Each new skin is larger than the previous one.

Now the caterpillar stops eating. It appears to shrink in size. It starts winding a continuous thread of silk filament around its body. The completed cocoon is much shorter than the caterpillar which wove it. Spinning takes about five days. About 600 to 900 metres of silk fibre is produced during this period by one caterpillar.

Within 15 to 20 days of the formation of cocoon, the adult moth emerges by breaking open the cocoon. It soon lays its eggs and then dies. But broken cocoons are not good for preparing silk threads. Much silk is wasted if cocoons are broken by the moths. Hence, the insects inside are killed by putting cocoons in boiling water.

The silk filament of a cocoon is very fine. In order to produce a thread that can be safely handled, several filaments from different cocoons are combined, twisted and wound on a reel or spool. A single good cocoon may provide as much as 700 metres of good filament. This reeled silk thread is

known as raw silk.

From one gram of eggs (containing about 700-1400 eggs), it is possible to get about 1,500 grams of cocoons or about 150 grams or raw silk.

In the cultivation of silkworms an abundant supply of green mulberry leaves is very essential. A kilogramme of cocoon needs 16 kilogrammes of good mulberry leaves. Besides a careful control of temperature and humidity, absolute cleanliness and abundant fresh air are also very essential for successful silk production.

5(c). WOOL IS OBTAINED FROM ANIMAL FUR

Wool is obtained from various animals such as sheep, llama (in South America), camel and goat. Of these, the sheep is the most common source for wool. The hairs of wool are scaly and curly.

Wool is collected by shearing sheep. Like silk and cotton, it is a fibrous material, and can, therefore, be spun into woollen threads or yarns. The children can develop this understanding through the following activities.

Field Observation

How is wool obtained from sheep?

If possible, invite children to a shepherd's house while he is shearing sheep. If such a visit cannot be arranged show appropriate pictures to the children. Help children observe how the shepherd washes the sheep before shearing.

Discuss with children why the hair of only certain animals can be used as wool. (The hairs should be such that they can be spun into threads.)

5(d). FIBRES ARE SPUN INTO YARN AND WOVEN INTO CLOTH

Whatever the fibre, it looks raw and crude in its natural state. The raw material has to be combed (or carded) and then spun into thread, often called yarn. The yarn is then woven into cloth by using looms. The process of combing and spinning varies from fibre to fibre. The children will understand this sub-concept better if they do the following activities.

Class Project

How are cotton and wool spun into thread?

Materials required
cotton
wool
spindle shaft

Help the children to make a crude spindle by fixing a smooth thin stick into a disc. Ask them to collect raw cotton and wool. Let them clean the materials. Guide them to twist some fibres together and tie the thread so formed to a groove made at the top

of the shaft. Spin the shaft. As the shaft of the spindle spins, thread will be formed as shown in Fig. 6-15. The same may be done with wool.

Fig. 6-15
Cotton and wool can be spun into threads.

Plan a trip to a gramodyog *centre to show the process of spinning and weaving. Take them to a cotton or woollen textile mill. Arrange a visit to one of the basic schools.*

5(e). SCIENTISTS HAVE DEVELOPED MANY KINDS OF ARTIFICIAL FIBRES

It has been discussed how raw material for cotton, woollen, linen, and silk fabrics is obtained from natural sources. But scientists have now developed methods to prepare what are known as 'artificial fibres'. These are produced by bringing about physical and chemical changes in materials either obtained from nature or prepared by scientists in their laboratory. For example, rayon or artificial silk is prepared from such naturally occurring materials as cotton, wood etc., and is called man-made or artificial fibre. Nylon, decron, and terylene fibres are prepared from simpler substances by scientists and are called synthetic fibres. These sometimes have very useful properties. For example, decron and terylene do not wrinkle easily. Besides this, some of the fabrics made from synthetic fibres wear very well as compared with those made from natural fibres. Children can be helped to understand these ideas about synthetic fibres through the following activities.

Discussion

How do the common fibres differ when seen under a microscope?

Make drawings on the blackboard of the common fibres (cotton, wool, silk, rayon, linen and nylon) as they would look under a microscope, as shown in Fig. 6-16. Help the students compare these magnified views. Discuss why woollen goods usually feel rough (because of their curly fibres) while those of rayon, nylon, silk and cotton feel so smooth.

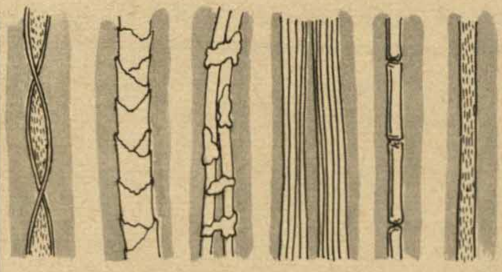


Fig. 6-16
Fibres of cotton, wool, silk, rayon feel different because they have different structures.

Discuss with children why artificial fibres have almost the same thickness throughout their length. (Conditions are so controlled during their preparation that the same thickness of fibres is maintained.)

In the preparation of synthetic fibres, two stages can easily be recognized. First, the synthetic material for fibres is prepared. Secondly, the synthetic material is converted into the form of long thin threads from which the cloth is woven. While it may be difficult for children to understand the complex changes involved in the preparation of the synthetic material, the preparation of fibres can be made clear through the following activities.

Discussion | **How are synthetic fibres made?**

Discuss with children how *sewain* (the long filament-like edibles made of flour) are prepared as shown in Fig. 6-17. One way of doing this makes use of a small machine. Here the dough is pressed against a plate with many small holes, and thus forced to take the shape of filaments on the other side of the plate. Help children understand that, somewhat similarly, fibres are obtained by forcing the synthetic material through very tiny holes.

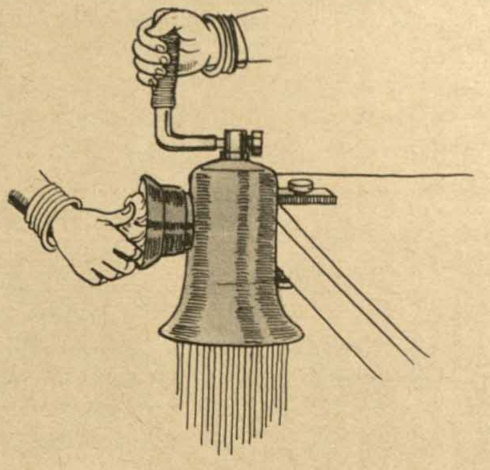


Fig. 6-17
This *sewain* machine suggests one way of making synthetic fibres.

Nylon socks are much more durable than cotton ones. Discuss with children why it is so. (It is due to the basic property of nylon fibres.)

6. FIBRES ARE SPUN INTO THREAD AND YARN: THESE ARE THEN WOVEN INTO CLOTH

In ancient times people spun fibres into yarn by hand. They used hand spindles for this purpose. Even today, such spindles can be found in this country among the people of the villages. The *charkha* is the most common device for spinning cotton into thread. This way of spinning was encouraged by Mahatma Gandhi. It has become a cottage industry nowadays. The other fibres like wool and silk were formerly spun into yarn in the same way.

With the advent of machines, the spinning of fibres into threads has been made very easy and quick. The texture of the yarn has been improved.

In a cottage industry, the cotton cloth is made by using handlooms. Such a cloth is called *khadi*. The texture of the cloth made by hand may not be as fine as that of mill cloth. However, it is much more attractive and useful. Making cloth by handlooms is a slow process. Nowadays, cloth of various types is made by machines in the mills.

6(a). SPINNING-WHEELS AND HANDLOOMS ARE USED FOR MAKING HANDMADE CLOTH

Most children have seen the spinning spindle and the spinning-wheel. It is likely that some of them may also have seen a weaver at work on his handloom. These were the only methods used in preparing cloth about three centuries back. Even nowadays some cloth is made by these old and simple methods of spinning and weaving. In order to help children develop an understanding about this method, invite them to the following activities.

Field Observation

How is cloth for our shirts made?

Plan a visit to a nearby village house where spinning is carried out as a cottage industry. You can even show the process of making cloth by handlooms, if possible.

Encourage the children to ask their parents to demonstrate, if possible, the spinning of the fibre into thread. Let the children collect loose cotton fibres, and by means of a crude spindle, spin out a thread, if possible.

6(b). POWER-LOOMS AND MILLS ARE USED IN MODERN INDUSTRY

Nowadays, machines are used to prepare cloth. Power-looms and mills manufacture cloth very fast so that the cost of production is far less than that of the handmade cloth. To understand the topic better it is advisable to allow the children to have first hand knowledge through activities such as these.

Discussion — **How does mill cloth differ from khadi ?**

Ask children to bring pieces of mill-woven cotton cloth and handmade *khadi*. Mix all the samples brought by children. Invite them now to separate these pieces into two groups labelled (i) handmade (ii) mill-made. Help them observe the differences between the two types of cloth. (In mill cloth threads are finer and of uniform thickness.) Discuss why there is so much uniformity in machine work.

Encourage children to discuss their preferences for hand-made or mill-made cloth. Let them argue their cases.

Discussion — **Why do mills make cloth faster than handlooms?**

Engage the children in a discussion. Why does a power-driven mill grind wheat into flour much faster than the hand-driven grinding stones at home? There are a greater number of revolutions per minute of the millstones because they are power-driven. Help the children now to understand that there would be much faster spinning with power machinery for that very reason. Let the children analyse the simple operations involved in hand-spinning. What parts of the *charkha* revolve? What parts move forward and backward. Power-spinning does all these operations very quickly.

Arrange a visit to a cotton mill if there is one nearby. If it is not possible, show students the picture of a textile machine in action. Discuss its operation.

Let the children discuss why mill cloth is cheaper. (The production is so high.)

7. CLOTHES LAST LONGER WHEN WELL CARED FOR

It is common experience that a machine or an item lasts longer if it is maintained properly and regularly. This is true of clothes, too. Clothes should be kept clean not only for preserving them but also for healthy living.

The clothes, therefore, should be laundered, dried, and mended as soon as they need repairs. If there be any stain it should be removed immediately by proper means. Stains are of many kinds. Each type of stain needs special treatment.

Cotton clothes should be washed with washing soda or soap. Soap and washing soda remove grease and dirt. In order to press the clothes they should first be dampened. Silk fibre needs different treatment in washing because the caustic soda in ordinary soap many damage the fibres. Dry silk in the shade. Wool, which is affected by washing soda, should be washed in warm water and mild soap. Wool is often 'dry-cleaned'. Wool and silk fibres are attacked by insects such as silverfish and hairy worms, known as wool weevils. When storing away the woollen clothes, it is a common practice to use naphthalene or D.D.T. for protection against these insects. Naphthalene balls or *neem* leaves are put in the folds of the clothes.

7(a). PROPER LAUNDERING, DRYING, PRESERVING AND MENDING MAKE CLOTHES LAST LONGER AND SERVE BETTER

In order that the clothes may serve better and last longer, it is necessary to wash them with care. Damp and musty clothes are put in the sun to dry. Sunlight also helps in keeping the clothes free from germs and insects. By washing and drying, the clothes are preserved better and, therefore, last longer. Whenever there is a tear or a threadbare spot, it should be darned or mended as soon as possible.

Different cloths need different precautions for their washing. While cotton clothes can be treated with soap and boiling water for washing, silk and woollen garments would be damaged in this way. Here are some activities that will help children in the development of this understanding.

Investigation | **Are different types of cloth washed in different ways?**

Wash strips of different types of cloth by different methods. For example, one sample from each may be washed with boiling water containing dissolved soap as shown in Fig. 6-18. Another batch of strips may be washed with water and detergent at room temperature. Compare the effects of washing on the different pieces of cloth. Show

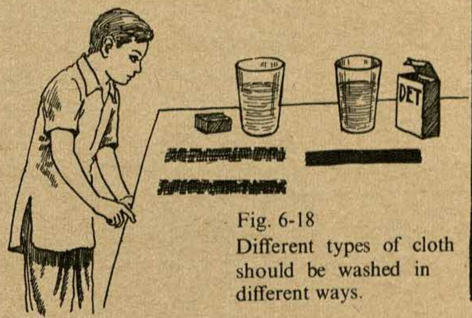


Fig. 6-18
Different types of cloth should be washed in different ways.

to children that cotton clothes are not affected adversely by hot water, strong soap solution or strong beating with a club. On the other hand, silk and woollen cloth needs special care in washing.

Discuss with the children the significance of 'A stitch in time saves nine'. How does mending in time increase the period of serviceability of clothes.

7(b). STAINS SHOULD BE IMMEDIATELY REMOVED BY PROPER MEANS

Removing spots and stains is becoming a common practice in the home. However, certain safety precautions should be observed. Common spot-removers are benzene, petrol, naphtha or carbon tetrachloride. Benzene, petrol and naphtha are highly inflammable and children should be warned not to use them by themselves.

Grease and oil stains may be removed by using any one of the following: carbon tetrachloride, benzene, naphtha or petrol. Other stains can be removed in other ways. In order that the children may gain first-hand experience of removing some of the common stains encourage them to do the following activities.

Class Project

How can I remove the ink stain and grease spot from my garment?

Materials required
a few pieces of cloth
ink
grease
soap
talcum powder
petrol

Ask the children to bring a few pieces of cloth, some made of cotton and some made of wool. Let them also bring some corn starch or talcum powder or salt (powdered) and grease or oil, and petrol. Ask the children to put a drop of ink on the cloth. While it is wet let them apply talcum powder or powdered salt. Ask them to work the powder into the stain. Repeat the process again after dusting the powder. When dry powder does not absorb any more of the ink in the stain, make it into a paste with warm water and apply it again. When the ink in the stain has been absorbed wash it with soap as shown in Fig. 6-19.

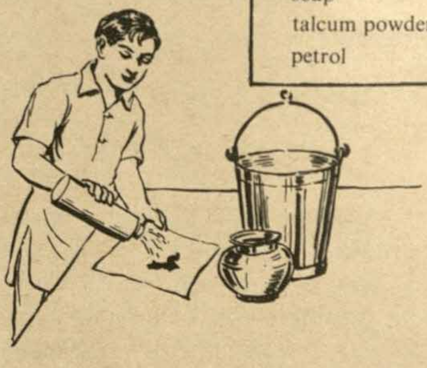


Fig. 6-19
Ink stains can be removed by washing after first treating with some common chemicals.

Next, ask the children to apply a little grease on the cloth at one spot. Then ask them to soak the cloth in petrol. Rinse it, and allow it to dry. To remove the smell of petrol, wash the piece of cloth with soap and water.

Let the children ask their parents what materials they have used for removing stains.

For Better Understanding

A few basic rules should be observed for removing stains. Stains should be treated promptly while they are fresh. If not, they may harden and set, making their removal more difficult. In addition, if they are not promptly removed, the stains may damage the fabric itself.

Before starting to remove a stain, one should determine the nature of the fabric-material. Can the material withstand washing? Is it affected by acids or alkalis? Will the colour fade at the spot where the stain is removed? It is advisable to test the stain-remover first on a similar type of cloth before using it on the clothes.

Coffee and tea stains can be removed from washable materials by ordinary laundering. If the stain is on wool or silk, sponge immediately with cold or lukewarm water. If a grease spot remains, treat it with carbon tetrachloride.

7(c). CLOTHES MUST BE PROPERLY WASHED TO REMOVE DIRT AND GREASE

Washing with soap or washing soda is a common experience with children. To help them realize that soap and washing soda help remove grease or dirt, invite them to participate in the following activities.

Investigation

How best can I remove dirt and grease from my clothes?

Materials required
washing soda
soap
cloth-pieces

Invite children to collect waste cotton cloth-pieces soiled with dirt and grease. Let them wash these rags, one by one, by different methods. One may be washed with washing soda, another with soap, another with plain water and so on. Help children observe that different methods are effective to a different extent in removing dirt and grease as shown in Fig. 6-20. Discuss which is the best method.

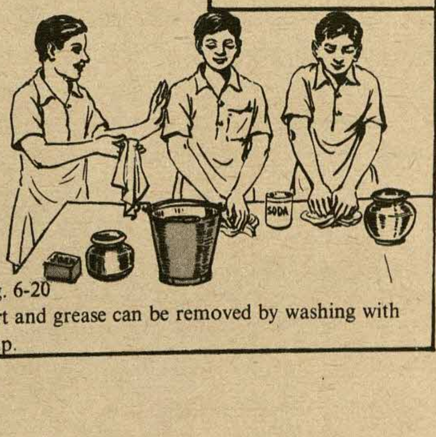


Fig. 6-20
Dirt and grease can be removed by washing with soap.

Let children compare the effectiveness of warm water and cold water while washing with soap.

7(d). CLOTHES SHOULD BE DAMPENED BEFORE THEY ARE PRESSED

Dry cotton or wool fibres have numerous air spaces. If one tries to press the fibres of the dry cloth it does not fully yield to the press. It is, therefore, necessary that clothes should be dampened before they are pressed. By dampening, the fibres are made to come together. The heat of the iron changes moisture to steam, and the weight of the iron presses the fabric flat. The children will understand this idea better if they are invited to do the following.

Investigation

Are damp clothes ironed more easily than dry ones?

Materials required
iron press
cloth

Let the children try and remove the creases in the rags that were washed in the activity for sub-concept 7(c) by using a hot iron, first when they are absolutely dry, and then again when they are dampened. Let them observe which one appears to be better pressed.

Invite children to go to a laundry and see how clothes are moistened before being pressed.

7(e). SILK CLOTHES MUST BE WASHED WITH GOOD QUALITY SOAP OR *reetha* AND DRIED IN THE SHADE

Silk, being an animal fibre is attacked by caustic soda and also by washing soda. It is, therefore, necessary that the soap used for washing silk clothes must be a mild soap. It should not give strongly alkaline solutions that would damage silk clothes. After washing, the wet silk cloth should be dried in the shade. Direct rays of the sun make the silk fibres shrink as they dry. The cloth thus becomes wrinkled. The children will realize the importance of the above facts by obtaining first-hand experience through the following activities.

Investigation

Do caustic soda and the sun damage silk?

Materials required
silk cloth
caustic soda
source of heat
enamelled vessel

Let the children collect different pieces of silk and cotton clothes. Make a dilute solution of sodium hydroxide by dissolving four teaspoonfuls of it in a litre of water. Boil the solution in an enamelled or porcelain vessel. An

Fig. 6-21
Caustic soda in water damages the silk fibre.

iron vessel will also serve the purpose. Do *not* use an aluminum vessel. Care should be taken when adding caustic soda to water. Boil the solution *gently*. With tweezers or forceps, drop the samples of cloth in the boiling solution. Allow it to boil for about 10 minutes. You will find that the silk fibres have dissolved as shown in Fig. 6-21. Next take two wet pieces of silk cloth. Dry one in the sun and the other in the shade. Ask the children to observe the difference between the surfaces of the two pieces after they have been dried.

Encourage children to compare the washing action of reetha *against that of any detergent such as Det or Surf.*

7(f). WOOLLEN CLOTHES MAY BE DRY-CLEANED

Wool, like silk, is an animal fibre. Strong soap is harmful to wool. Woollen clothes, therefore, should not be washed with strong soap. Woollen clothes are often dry-cleaned. It is called dry-cleaning because the clothes are not moistened with water. Common liquids used for this purpose are petrol carbon tetrachloride, and benzene. Children can learn more about dry-cleaning through the following activities.

Investigation

What is the proper way for washing woollen clothes?

Materials required
pieces of woollen cloth
soap
petrol

Invite children to carry on the activity as in 7(e) with regard to the use of strong soap for cleaning woollen material. Then ask the children to wash some dirty pieces of woollen cloth by soaking them in petrol. Let the samples be taken out. Be careful to see that the petrol drips off completely before putting them to dry. Be sure that no flame or glowing charcoal is anywhere near the petrol. The children will discover that strong soap damages woollen cloth. Petrol will be found to be good for dry-cleaning woollens.

Ask children to learn from the nearby laundry what chemical

they are using for washing woollen clothes. Let them find out why dry-cleaned woollen clothes have a typical odour.

7(g). INSECTS CAN DESTROY WOOLLEN AND SILK CLOTHES

The two animal fibres, wool and silk, are often attacked by silverfish and by wool weevils. The wool weevils are light hairy insects. They eat into the wool and destroy the cloth. Care must be taken to kill these pests or at least to keep them from living inside the clothes. This is best done by drying the clothes in the sun before packing them away. The woollen clothes should be packed along with naphthalene, or the cupboard should be sprayed with D.D.T. before storing the woollen clothes in it.

Children have already had this experience by observations at home. Help them recall their experience by questioning them as follows.

Familiar Experience

How do we protect woollen and silken clothes from insects?

Where do you store your woollens in summer? Do you use any means to protect them from insects? Have you ever seen a silverfish? (Some may have). If so, what does it look like? Is it found among the cotton clothes? Have you seen any other insects among the woollen clothes? Have you seen woollen clothes destroyed by insects? What happens to the wool which has been removed to make a hole? When you have finished with questioning and have obtained satisfactory answers, help children conclude that chemicals like naphthalene and D.D.T. protect clothes from insects that eat woollen and silk clothes.

Engage children in a discussion : Which bush-shirts are best—cotton, silk, or synthetic fibre? Encourage each child to argue his case.

Scientists at Work

Science helps in making better cloth

Today let us hear the story of cloth-making. The garments you wear are tailored out of cloth which has been prepared from a raw material like cotton, wool or silk. This is the story of cloth-making from these raw materials.

Any cloth-making process involves (i) spinning of raw materials into threads, and (ii) weaving of the threads

into a piece of cloth. Some of you might have seen people spinning thread out of cotton from a spindle or a spinning-wheel. This is a slow and tiring process. A few of you might have also seen a weaver preparing cloth from such threads. This again is a slow process. The spinning-wheel was first used in India and Persia many hundreds of years before America was discovered. From there it was brought into Europe about the year 1300. The entire process of cloth-making by this old method was so slow that only the richest people could afford more than one or two dresses.

Like spinning, the early method for weaving was also a slow process. The looms used for weaving were simple frames as wide as the cloth to be woven. Into the lower edge of the frame were fitted a number of bent nails in a row. A ball of the thread was attached to each hook. The thread from each ball was stretched tightly over the frame from bottom to the top. These threads were known as the *warp*.

Warping the loom was only half of the process of weaving. A new thread was used to weave in and out of the warp threads. This weaving thread, called the *woof,* ran from left to right. Between any two adjacent warp threads, the woof went over one and under the next. The woof thread was wound on a small boat-shaped piece of wood called the *shuttle*. Drawing the shuttle alternately below and above the warp threads was a very slow and laborious process.

The first improvement in the loom was made when some person devised a method of moving each set of warp threads together by a single stroke. The method consisted in attaching all odd threads to one bar and all even threads to another. All odd threads were then lifted up forming a sort of tunnel through which the shuttle and its woof thread could be woven by a single movement. After this the odd threads were lowered and the even threads lifted. Again a tunnel was formed and the woof thread passed through it.

Like many others, John Kay, a poor English weaver, was tired of the slow progress of weaving even after long hours of work. The sideways throwing of the shuttle must have bored him the most for he thought of devising a convenient way of doing this. And he did it.

At each side of the loom, he placed a little box. After its trips through the warp threads, the shuttle rested in either of these little boxes. In each box there was a little rod. Both these rods were joined to a common cord in such a way that by pulling the cord, the rod could be made to jump and kick the shuttle across the warp threads. The shuttle then came to be called a *flying shuttle*.

Kay was extremely delighted with his invention. How much labour he was able to save by this device! And how much more he could weave by this simple improvement in the loom!

Kay's fellow weavers were not happy at this invention. They thought Kay's shuttle would enable a single weaver to produce so much cloth that many weavers would not be able to earn

their livelihood. They broke into his house and smashed his loom. Kay had to flee.

People knew even in those days, as we know it so well now, that a technological change can have a profound influence upon the workers' conditions. New ways of doing things are usually accepted with difficulty by a society.

Kay's invention was followed by several others. James Hargreaves invented a spinning-jenny (named jenny by Hargreaves in honour of his wife) in which eight spindles turned simultaneously by the movement of a single wheel. Thus not one, but eight threads were spun in one operation.

Richard Arkwright, the inventor of the water frame, a spinning-machine operated by water power, was neither a spinner nor a weaver, but a barber. He desired to make a machine that could spin as fast as the spinning-jenny and yet produce finer thread. With the help of a clock-maker, Arkwright was able to devise such a machine. He became extremely wealthy through this invention.

The story of cloth production develops around three kinds of devices: (i) those used for preparing raw fibres, (ii) those used for spinning, and (iii) those used for weaving. A close study of the development of cloth production through the various stages shows that raising the efficiency of one tool demands a corresponding increase in the efficiency of other tools. If a machine was developed that could spin very rapidly, efficient methods or preparing raw materials and quick methods of weaving to consume the rapidly produced yarn must also be developed.

Cartwright developed a loom, a weaving-machine that could weave very rapidly. With the growth of spinning and weaving mills it was found that cotton seeds could not be picked from the raw cotton rapidly enough to feed the mills. Eli Whitney, the son of an American mechanic, invented a cotton gin (short form for cotton engine). It could clean the seeds from cotton very rapidly.

So, that is the story of cloth production as it developed during the hundred years of the 18th century. It is a story of man's progressive use of machines in the production of cloth. Developments of a similar type in other fields of production ushered in the age of the Industrial Revolution. Mass production by machines became a firmly established practice in this age. Machines were used to manufacture things on a very large scale. The speciality of the machine was that things were produced very rapidly and were exactly alike. Man simply made the machines and supervised their work. Now, of course, machines are being built that can even supervise the work of other machines.

How productive are the ways of science! How useful are even the little discoveries made by individual scientists for the entire human race! How deeply involved is the good of the entire community in the efficient working of individuals!

UNIT 6

HOUSING AND CLOTHING

CLASS V

Overview

Children have learnt in previous classes that a house should offer comfort, convenience, safety and healthful, hygienic conditions. They also know that houses may be of very different types. For example, they may differ in their designs, or in materials used for constructing walls, roofs, floors, etc. In this unit, investigations are made to find out *why* houses exhibit this much variety.

The idea that houses are constructed to give protection from natural forces and from enemies is discussed in the first major concept of this unit. Somewhat similar concepts have been discussed in class I and class III. These ideas about protection and safety are discussed at a little higher level in this class.

In the second major concept discussion concerns how house-building is influenced by climate and economy. The treatment of this unit is in this way related to the living conditions of a society. Houses are built by men living in a specific social and physical environment. It is, therefore, very interesting to find how this environment affects the house-building activity of man.

What is the best way to teach the above concepts? Children may be helped to make relevant observations at home or in the neighbourhood. The data about house construction collected in this way is then discussed in relation to the functions performed by different parts of the house.

1. HOUSES ARE CONSTRUCTED TO GIVE PROTECTION FROM NATURAL FORCES AND FROM ENEMIES

Man developed clothing to protect himself against the changing weather and against insects. He has developed houses in an attempt to create conditions in which he could work and rest with maximum comfort by protecting himself from the natural forces such as the wind and rain, heat and cold, insects and vermin.

The roof and walls of a house are meant to ward off the sun, rain, and wind. To do this the materials used must be such as to allow the rain to drain off easily. They should be opaque and thick enough to insulate against the heat of the sun. The walls should be thick and strong enough to withstand the onslaughts of wind and storms, and also the common natural enemies of man—the insects and vermin. In addition,

the walls and rooms must be built so that they keep the thieves away.

Windows should let a sufficient amount of natural light into the rooms. However, they should be so constructed as to allow only the early morning and the late evening rays of the sun to enter the room. Windows allow fresh air to enter a room and impure air to be carried away from it.

The following sub-concepts are intended to make these ideas more clear to students.

1(a). THE ROOF AND OUTSIDE WALLS SHOULD BE CONSTRUCTED TO WITHSTAND EXTREMES OF WEATHER AND KEEP OUT INSECTS, ETC.

In this country, many kinds of roofs are in use depending upon the climate of a particular place and the financial position of the person to whom the house belongs. But whatever the type of roof, it serves the purpose of protecting the house against wind, rain and sun.

The structure of the walls, depends upon the conditions given above. In Rajasthan, the walls of the houses are built thick to keep away the intense heat of summer. In hill stations like Mussoorie and Darjeeling, where it is very cold, thick walls are built to withstand the severe cold of winter. High roofs also help in keeping a house cool during summer. The slope of the roof helps to drain the rain water easily. In places of scanty rainfall the roofs are usually flat. These flat roofs are used for sleeping during the nights in summer. Another useful purpose of the roof and walls is to prevent insects and pests from entering the house.

The sun first heats the external walls and the roof of a house. Gradually the interior of the house also becomes hot. Walls and roofs should be constructed in such a way that they provide good insulation. They should be strong enough to resist the eroding effects of wind and rain. Children can be helped to grasp these ideas through the following types of activities.

Field Observation

How do different types of walls and roofs protect us from the weather and insects?

Ask children to observe the roofs and outside walls of the houses in their locality. If possible, they may extend their observations to a nearby village, town or city. Help them discuss how efficient the various kinds of walls and roofs are for protection against sun, rain, wind and insects.

Encourage children to make a drawing of a roof. Let them display in the classroom, in the form of a chart, the drawings of different types of roofs.

1(b). DOORS AND WINDOWS SHOULD PROVIDE ADEQUATE LIGHT AND VENTILATION

Doors serve as entrances and exits for rooms. Besides, they allow light and air into the room. The primary purpose of a window is to bring in enough sunlight and fresh air. When closed it protects against wind and rain. Sometimes doors and windows are fitted with glass. This allows light to enter the room from outside even when doors and windows are closed. Children however, do not pay much attention to such details. To make them realize the importance of doors and windows for light and ventilation ask them to carry out the following activities.

Familiar Experience

How are doors and windows useful in our houses?

Invite the children to observe the situation of the doors and windows of their classroom. Discuss with them such questions as: Are the windows facing each other? Which way does air enter the room? What is the size and height of the windows? If there is a brisk breeze blowing into the room ask them to shut the doors and windows of one side. Inquire if they feel the same amount of breeze after this action. Through a discussion based on such questions help children realize that doors and windows provide for adequate light and ventilation.

Ask children to draw the figures of a few types of doors and windows found in their locality.

1(c). DOORS AND WINDOWS SHOULD KEEP OUT INSECTS, ETC.

To keep away rain, insects and vermin, doors should fit tight. Spaces and holes in the doors and their frames allow not only wind and rain but also rats and insects to enter. Mosquitoes are also kept out by using net-screen on the doors and windows. Help children to realize the importance of this sub-concept by asking the following questions.

Discussion

Why should we have wire nets on tight doors?

Ask children if they think that it is essential for a classroom to have doors. If so, why? How can a door prevent water and wind from entering the room? How should you keep away flies from the classroom? Help children to conclude that tight doors fitted with wire nets keep the flies and other insects away.

Let children visit places where doors are tight and are fitted with wire nets. Let them also visit places where such things are absent. Discuss what difference children find with regard to the entry of insects. Why are such wire nets very essential in kitchens?

Discuss with children the development in the construction of windows. Originally they were thought of as openings to allow entry of air and light. For safety they were fitted with iron bars and doors. Fixing wire nets helped even further by keeping away insects, etc.

For Better Understanding

It is not common to find doors and windows fitted with wire nets even in cities. Probably this is because the fitting of wire nets on doors and windows is costly. It may also be due to a lack of a sense of urgency about keeping the flies and insects away. The teacher can aid the community a great deal by helping the children see the need for cleanliness in this respect.

The fixing of wire nets may appear to be quite costly in the beginning. Yet, judging from the protection they provide against many diseases, the expense is worthwhile. It is for this reason that the fixing of nets has been given due importance in this sub-concept.

Wire nets may be substituted by such easily available materials as clean, worn-out saris or other light, loose fabrics. They would also prevent insects, and yet would allow air to come in.

1(d). DRAINAGE WATER OUTLETS SHOULD HAVE BAR NETS TO PREVENT ENTRANCE OF ANIMALS

Every well-constructed house has a good system of drainage. But where the drain-pipes emerge from the house, some holes are usually found. These should be properly sealed. For every drain-water pipe that is connected to the main sewage pipe, there is a *water trap*. These traps should have a covering. Otherwise, the outlets serve as a place where rats, mice, and snakes may enter the house. The activity suggested below will encourage the children to observe more carefully what they might have taken for granted.

Class Project

Are the drainage outlets of our community well designed?

Invite the children to carry out a survey of the drainage system of the school premises. Let them carry on the same sort of survey of houses in their locality. Ask them to record their observations as given below:

1. Number of houses visited
2. Number of drain-water traps
3. Number of drain-pipe outlets
4. Number of covered drain-water traps
5. Suggestions as to how to close them effectively against the entry of rats, mice and snakes.

Encourage the children to visit a village and inspect the drainage system and make suggestions for improvement.

Ask the children to make a chart of a good drainage system. They may take the help of a local doctor or health official.

2. HOUSE-BUILDING IS INFLUENCED BY CLIMATE AND ECONOMY

Even in primitive days, when man selected a cave for shelter, he was guided by the factors of the environment. He selected a particular cave, maybe because it was very close to some source of water and food, maybe because it afforded a good shelter from the wild animals which roamed near his cave. Or, maybe he was prompted by the necessity of taking shelter from the forces of nature like the sun, the rain and the wind and wanted a place for himself and for his family. Thus those primitive people were in some ways not different from the people of today in their search for shelter. Climate and surroundings were important considerations in the selection of a cave; and they are still the important factors in selecting the design and location of a modern house.

A house in a desert would not be the same as a house in a place with heavy rainfall. A house in the Arctic regions would be quite different from a house in a hot country. A man also has to consider his financial position when building a house. This will determine the size of a house and the materials of which it is made.

Whatever be the types of materials used, it should be borne in mind that the building materials need great care. This may be done by washing, polishing, painting, varnishing, creosoting and whitewashing. In the sub-concepts which follow, learning activities provide first-hand experience to help students comprehend these ideas.

2(a). THE HOUSE-BUILDING OF A LOCALITY IS INFLUENCED BY THE AVAILABILITY OF MATERIALS IN THE LOCALITY

It can be easily realized why the building of a house is conditioned by the availability of materials in the locality. Jaipur in Rajasthan is known as the 'Pink City'. It has many houses built of red sandstone which is so common in that area. Similarly, where clay and brick kilns are plentiful, one can find brick or clay buildings. In the coastal regions of South India, people have thatched roofs for their houses. Here coconut trees

are in abundance and the dry palm leaves and coir are very cheap. Thus the renewal of thatch, even every year, does not cost much. Invite children to carry out the following activities to help them understand the above concept.

Field Observation

How are houses in a village different from those in a city?

Let children observe as in Fig. 6-22 the different materials used in constructing houses in their locality and then compare them with the materials used in a village or a city. Encourage them to list reasons for differences in the house building materials.

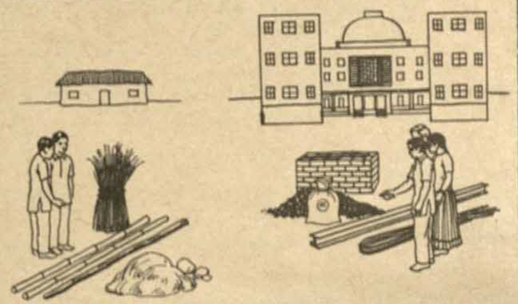


Fig. 6-22
Houses in villages are often built of different materials than are houses in cities.

Ask the children to prepare a chart by collecting pictures of different types of houses and label them as follows:

Type of house	Place where commonly found

Encourage the children to collect different materials used in constructing a house. Let them display their collection in the classroom. Each material should be labelled and described in a sentence or two.

2(b). AVAILABILITY OF MONEY AFFECTS HOUSE DESIGN

A person who can afford to spend a lot of money generally builds a big house. He gets it designed in such a way that it looks attractive. A poor man with limited resources builds a small house. He generally uses the cheaper variety of materials. In order that the children may appreciate this sub-concept an activity such as given below may be performed.

Field Observation

How does an expensive house differ from a cheap one?

Invite the children to go round the locality and observe the type of house in which each family lives. Let them relate the type of house to the financial

status of the person who lives in the house. Encourage the children to discuss the observations they have made, as in Fig. 6-23.

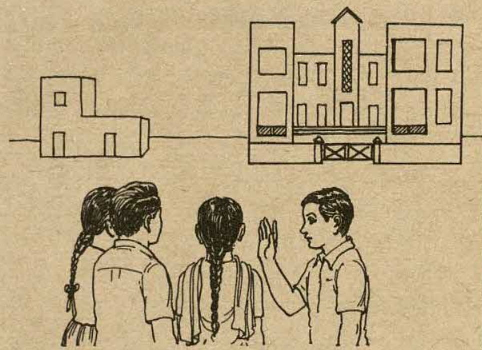


Fig. 6-23
An expensive house differs from a cheap one in many ways

Encourage children to compare the buildings of a guest-house, rest-house, and dharmashala *with the house of a labourer.*

2(c). DIFFERENT MATERIALS REQUIRE DIFFERENT METHODS OF CARE

Whether mud, stone, cement, or wood, is used to build a house, it is necessary that the materials must be cared for and maintained. There are various ways of doing it and various materials need various methods to maintain them in good condition.

Cement floors and walls need to be washed. Wooden and iron ones need to be polished and varnished or painted. Paint prevents corrosion caused by water and weather. Painting also prevents warping and rotting by closing the pores in wood. Spraying wood with creosote protects the wood from being attacked by termites (white ants).

Whitewashing the walls and ceilings prevents dampness setting into the plaster of the walls. In addition, whitewash or distemper kills germs on the surface of the walls and roofs. The children will understand the value of protecting the building materials by doing the following activities.

Investigation

How can wooden and metallic articles be protected?

Materials required
varnish
paint
whitewash, or turpentine
kerosene
wood-pieces
metallic straps
pan balance and weights

Ask the children to bring varnish, paint, whitewash, turpentine or kerosene oil and iron nails and pieces of wood. Let the children take a few pieces of wood and weigh each one. Let them note the weights. Ask them to cover each piece of wood with a different covering material. Let them leave one piece of wood without a covering. Invite the children to put each piece in water for an hour or so. Ask

them to take the wood and nails out after an hour and examine them as in Fig. 6-24. What difference do they find in the weights now? Ask them to draw their own conclusions. Let some more pieces of wood be covered with materials as before. Apply a candle flame or spirit flame to each piece of wood thus covered. Which one catches fire quickly? Which is the best material for protecting wood against fire and water? Through such questions children will conclude that painting protects a metallic or wooden surface.

Fig. 6-24
Paint protects iron and wood surfaces

Ask children to take some nails and rub them all with sandpaper. Now let them cover some nails with paint and leave others unpainted. Invite them to observe what happens to the nails which are exposed to air. Help students conclude that paint protects iron from rusting.

For Better Understanding

Wood and stone are the two common materials used for building houses. However, iron has become another important building material, specially in reinforced concrete buildings. Iron is also used for window grills and beams for the ceilings.

People, who build houses of wood, generally paint the wood to preserve it and give it weather-resisting qualities. Wood has pores in it. In unpainted wood, these pores may be filled with rain water. Fungi and wood-eating insects like termites thrive on wood that is wet. Wet wood rots easily. Wood also absorbs water. When wood absorbs water, its fibres increase in length, and warping occurs.

Painting, therefore, prevents warping and rotting by closing the pores in wood. Paints contain linseed oil and a lead pigment. The oil helps to form a protective coat when it dries. The linseed oil and the lead paint furnish a smooth surface that allows raindrops to slide off instead of sticking on the wood. Paint also contains substances which are poisonous to bacteria, fungi and insects.

Paint prevents iron from rusting. The presence of air (oxygen) and moisture are necessary for rusting. A coating of paint keeps away the moisture and air from the surface of iron. It thus prevents rusting.

Wood structures in a house are covered by tar so that termites may not attack and eat them. This is done especially for those portions of the wood that are either underground or inside the walls. Tar is a strong germicide and thus the wood is protected.

2(d). HOUSES IN AREAS WITH HEAVY RAINFALL OR SNOWFALL HAVE SLOPING ROOFS

In place with a heavy rainfall like Assam the roofs have to be so constructed as to allow the water to run off. This is effectively done by constructing sloping roofs. However, the roofs may vary in steepness.

In places like Darjeeling and Nepal, there is a heavy snowfall in winter. Snowfall tends to gather and harden under its own weight. If the snow is allowed to stay on the roofs, the weight of the snow may break the roof. To prevent this, the roofs are made to slope steeply. The children will understand this idea better by doing these activities.

Investigation

How quickly does water flow down a slope?

Materials required
a thick cotton cloth
wire frame

Ask the children to take a thick cotton canvas cloth. Let them stretch it out over a frame of wire. Ask them to sprinkle water on the cloth (i) when it is kept sloping and (ii) when it is kept horizontal.

Invite the children to comment on what they see.

Discuss with children why umbrellas are shaped as they are.

2(e). HOUSES IN VERY COLD CLIMATES HAVE WELL-INSULATED ROOMS

In places of extreme cold, the body needs warming even within the house. People use fires and hot-air or hot-water systems to heat the rooms; but unless the heat thus given off is kept inside the room, it will be of no use. If doors and windows are closed the loss of heat is mostly through the walls and the roof. Therefore, it is economical to insulate the walls and roofs of a house during construction. Point out to the children that good insulation will not only prevent the heat from escaping in the winter, but also will keep the heat out during summer. In order that the children may understand how insulation helps in keeping the rooms warm in winter and cool in summer, let them perform the following activities.

Investigation

How does a blanket keep a piece of ice cold, or water hot?

Materials required
blanket
vessels
source of heat
ice

Let one piece of ice be kept covered with a blanket and a similar piece left uncovered. When the uncovered ice-piece has partly melted, show the children that in comparison the covered ice-piece has melted less as in Fig. 6-25. Help children infer that the ice has been kept cold by covering with a

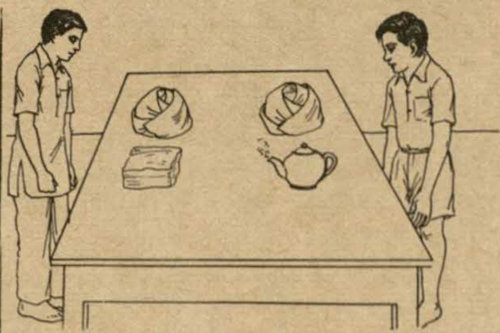


Fig. 6-25a

Fig. 6-25b

Fig. 6-25a and b
A cloth covering can keep ice cold or boiling water hot for sometime.

blanket. (Heat from outside is not allowed to reach the ice-piece freely.)

Repeat the experiment by putting boiling water in two vessels, but wrapping only one with a blanket. This time children will find that the water in the container covered with a blanket keeps hot for a much longer period. Discuss with children why the blanket keeps one thing hot and the other cold for a longer period of time. Explain to children that the blanket does not allow much heat to pass in or out through it. This helps it in keeping ice cool and boiling water hot. The blanket is a poor conductor of heat. It is a good insulating material.

Ask children to repeat the above activity with different insulating materials such as cotton, wool and sawdust. Let them find out which is the best material for preventing the flow of heat.

Scientists at Work

The story of mortar—the binding material for bricks and stones

Many houses are built by placing stones or bricks in layers. This has always presented the problem of binding the bricks or stones together into a solid wall. Such a binding material is known as *mortar*. Today let us talk about the story of man's search for an effective mortar.

The earliest mortar was probably mud prepared by mixing clay, water and chopped straw. Even nowadays it is used as a mortar for constructing walls of unbaked bricks in villages, where it is also used for plastering walls. Mud mortar is still sometimes used in constructing baked brick walls

in the interior of the house.

You might have heard of the pyramids that were built by the Pharaohs—the Egyptian kings—several thousands of years ago. They were built by piling up huge stones, each weighing hundreds of metric tons. You may wonder what mortar was used for binding these stones. The Egyptians used lime and gypsum mortar as a binder.

Some of you might have seen a big stone building like the Taj Mahal of Agra or Red Fort of Delhi. In these buildings also lime mortar was used. It is said that this mortar was prepared by mixing lime, sand and a number of fibrous materials. It was, however, a costly, tiresome and time-consuming process. But the mortar seems to work well since these stone walls have withstood the weather for several centuries. Even now ordinary lime-sand mixtures are used as mortar though they are not as effective as the specially prepared mortar used in the construction of large modern buildings.

Nowadays mortar is prepared by mixing cement and sand together, with or without some lime. The mixture is worked with sufficient water to form a thick paste. But what is this new component of mortar—*cement?*

Generally speaking, cement is any material that can be used as a binding agent to keep different materials together. Thus glue, plastics and solder may be called cements. Ordinarily the word cement means Portland cement, used widely for constructing dams, roads and houses.

About the middle of the 18th century there was a problem facing English builders about the erection of a new lighthouse. After conducting experiments, John Smeaton—an English engineer—succeeded in preparing a good mortar from lime. He prepared it by heating limestone containing considerable proportions of clay. This type of mortar has been used in our country for several hundred years. Some of the buildings so made are standing today.

Once it was known that a good cement could be prepared by heating a mixture of limestone and clay. Scientists worked to develop the idea. In 1824, Joseph Aspdin patented a method for preparing a hydraulic cement—one that sets when mixed with water. He called it 'Portland cement' because his material resembled a stone quarried on the Isle of Portland in the English Channel.

Limestone and clay (or slate) are the raw materials for the manufacture of Portland cement. Rocks are blasted out of the mountains and ground into fine powder by a giant crusher. The mixture of limestone and clay is heated in a huge round tube which is slowly rotated. This rotating tube is slightly tipped towards its mouth. As a result, the heated limestone and clay slowly move to the lower end. The heat-treated material is then crushed to a fine powder.

Cement is a very important material for the development of our country. It is used in huge quantities for the construction of buildings and dams.

The most important use of cement is in the preparation of concrete. Con-

crete is a mixture of sand, gravel and stone held firmly together in a solid mass by the cement. Concrete is very hard and strong. It is an indispensable material for all modern buildings. It resists the action of water. Hence concrete is also used in the construction of dams. In order to enhance further the strength of concrete, it is inlaid with a network of iron bars. This is then called *re-inforced concrete*.

Here we have been talking about such common materials as clay, sand and limestone. This story shows how man has been modifying these natural materials so that they may serve him better in the construction of buildings.